# JOURNAL of the
# SOCIETY of MOTION PICTURE
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## AUGUST 1950

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There will be nine technical sessions, at least five engineering committee meetings, five awards, two pre-release motion pictures, cocktail party, banquet, costume ball and five "open" sessions reserved for recreation.

**LAKE PLACID CLUB**
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*See page 216 for details.*

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# Characteristics of Motion Picture And Television Screens

By FRANCE B. BERGER

GENERAL PRECISION LABORATORY, PLEASANTVILLE, N.Y.

SUMMARY: Two fundamental factors, brightness gain and reflectance or transmittance, determine the suitability of a screen material in any particular application. High brightness gain, which necessarily implies a narrow viewing angle, may be desirable in one application but not in another. The reflectance or transmittance of the screen material is a measure of the light efficiency.

Comparative figures for several commonly used screen materials are presented. Both front and rear projection screens are considered. Fundamental photometric concepts are reviewed and laboratory equipment is described. The figures are considered to be accurate to within about 5%, and are in reasonable agreement with the few published figures available.

AT VARIOUS TIMES in the past we have needed quantitative information regarding particular screen materials used in motion picture and television projection. A search of the literature on the subject revealed very few published figures and very little uniformity in the nature of the figures chosen for presentation. The lack of uniformity may be attributed to the fact that there are several systems of photometric units in common use, and, further, that certain photometric terms have been defined differently by various authors. The necessity for subsequent interpretation of published data detracts from the value of the information.

To facilitate our investigation, we were obliged to review the necessary theory, choose a system of units and definitions, and construct equipment for measuring the essential screen parameters. The purpose of this paper is to review the work that has been done and to present the results of the measurements which have so far been made.

The brightness of a screen as viewed by an observer in the audience depends not only upon the illumination falling on the screen from the projection optical system, but also upon the directional properties of the screen. Observers at different positions in the audience may see different brightness levels, depending upon the angle from which they view the screen. The screen's performance in this respect is governed by certain fundamental optical properties of the screen material. Before these properties can be discussed, though, optical terms which apply alike to all projection screens should be defined.

Following the definitions, the basic optical characteristics will be described in as nonmathematical a manner as possible. An exact treatment requires a mathematical approach, but since the mathematics may often obscure the physical concepts under discussion, they are relegated to appendixes.

## Characteristics Common to Screens in General

Of the total incident light that is projected onto a screen, some is transmitted through the screen, some is reflected or scattered from the screen, and the rest is absorbed by the screen. The fraction of the total incident light that passes through the screen is called the *transmission factor* or the *transmittance* of the screen. The fraction which is reflected from the screen is called the *reflection factor* or the *reflectance*. The fraction which is neither transmitted nor reflected is called the *absorptance*. These three quantities are often expressed as percentages, their sum being, of course, 100%. For a front projection screen a large reflectance is desirable, and the transmittance is generally small. For a rear projection screen, large transmittance and small reflectance are desirable. The absorptance should be small in either case.

The color of a screen depends upon the spectral composition of the light projected onto the screen, and also upon the reflecting or transmitting properties of the screen material itself. Strictly speaking, the transmittance, the reflectance and the absorptance of a screen depend upon the wavelength of the incident light. For most purposes a projection screen should be "white," that is, it should reflect or transmit to the same extent light of all visible wavelengths. For the purpose of this paper we shall assume that we are dealing with white light and with white screens.

A screen material may be characterized as either specular or diffuse. The light transmitted by a sheet of glass, which passes through unchanged in its direction of propagation, is an example of *regular transmission*. The light reflected by a mirror leaves at a definite angle with relation to the angle of the incident light. Such reflection is referred to as *specular*. For convenience the term *specular* will be used in referring to either regular transmission or specular reflection. In contrast to specular effects, a beam of light falling on a blotter is reflected from the illuminated spot in all directions. A beam of light passing through a sheet of ground glass emerges in all directions. Such reflection and transmission are commonly referred to as *diffuse*. Diffusely transmitted or diffusely reflected light is referred to as *scattered* light.

Both the transmittance and the reflectance of a material can be separated into two parts, the specular and the diffuse. When this distinction between specular and diffuse transmittance or reflectance is not made, the term *total transmittance* or *total reflectance* may be used to so indicate. Most materials that are suitable for projection screens have small specular coefficients, and one simply refers to the "transmittance" or "reflectance" of the screen.

The relative amount, or intensity, of light scattered in the various directions is conveniently represented by a polar distribution diagram. Different screens have different scattering properties and are, therefore, represented by different distribution diagrams. A distribution diagram such as in Fig. 1A characterizes a diffusely transmitting screen. A screen material having appreciable specular trans-
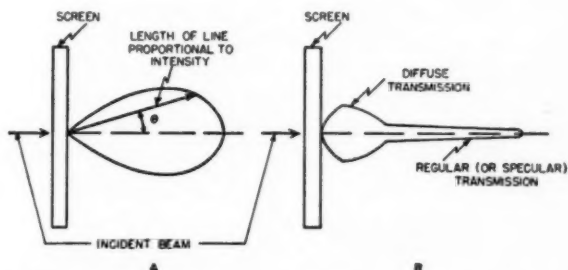


Fig. 1. Polar intensity distribution diagrams of rear projection screens: A, diffusely transmitting screen; B, screen exhibiting regular (or specular) as well as diffuse transmission.

mission in addition to diffuse transmission is represented by a diagram such as that shown in Fig. 1B.

Strictly speaking, polar distribution "diagrams" must be three-dimensional diagrams and the distribution "curves" are really surfaces. If the distribution is symmetrical about the normal to the surface, a simple plane diagram completely describes the directional scattering properties of the screen. If the distribution is unsymmetrical, and many practical screens have such unsymmetrical directional characteristics, the distribution is commonly represented by two plane diagrams; one for the distribution in a vertical plane, the other for the distribution in a horizontal plane.

In the examples cited, it has been tacitly assumed that the maximum intensity of the scattered light is observed in the direction normal to the screen surface. This may often be the case, but is by no means always true. In particular, if the direction of illumination is

oblique to the screen surface, the maximum illumination is often observed to be in a direction other than normal to the screen surface. Certain possible situations are represented by the diagrams in Fig. 2, which pertain to front projection screens.

It is well to emphasize that an intensity diagram and a brightness diagram are not identical. Intensity distribution diagrams have been used in the previous examples, but brightness distribution diagrams would have served just as well. The brightness in any given direction is proportional to the intensity in that direction divided by the
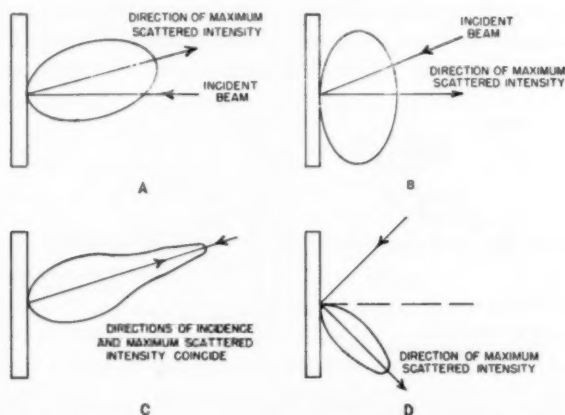


Fig. 2. Some of the possible types of intensity distributions for front projection screens: A, medium brightness gain screen with pattern asymmetrical with respect to the normal; B, diffusing screen with brightness gain less than unity; C, behavior typical of beaded screens; D, high brightness gain screen exhibiting marked specular behavior.

cosine of the angle between that direction and the normal to the screen. The two diagrams are therefore related.

### The Brightness Gain of a Screen*

The directional properties of a screen material can be represented to an extent adequate for many projection considerations by stating only a single numerical value. This value is the brightness gain. In order to define a numerical value for brightness gain, some specific directional characteristic must be chosen as a reference. We shall

* Discussion with Dr. W. W. Lozier following the presentation of this paper disclosed that the quantity herein defined as "effective brightness gain" has been called "apparent reflectance" by some investigators.

choose the particular scattering characteristic which defines a Lambert scatterer as our standard.

A Lambert scatterer is, by definition, one having a sphere tangent to the scattering surface as its three-dimensional intensity distribution diagram.  It scatters with greatest intensity normal to its surface.  Since it scatters symmetrically about the normal, it is adequately represented by its plane scattering diagram, which is a circle.  A Lambert scatterer is often called a perfect diffuser.

The brightness of a Lambert source, whether an emitter or a scatterer, is independent of the direction from which it is viewed.  The obliquity decrement in intensity is just compensated by the increase in source area corresponding to a constant projected area.  A perfectly diffusing surface emitting, transmitting or reflecting $N$ lumens per square foot of its area has, by definition, a brightness of $N$ foot-Lamberts, which remains the same for all directions of viewing.

Any screen can be compared with a Lambert screen scattering the same number of total lumens per square foot of screen area.  Let the brightness of the Lambert screen be $B'$.  Let $B_0$ be the brightness of the screen in question when it is viewed in the direction in which it has maximum brightness.  The brightness gain, $G$, of the screen can be defined as the ratio

$$G = \frac{B_0}{B'} ,$$

which is equivalent to taking the brightness gain of a Lambert scatter as unity.

The mathematical representation of brightness gain is discussed in Appendix I.  The above definition of brightness gain is in general use.[11]  It should be mentioned, however, that another definition is sometimes used[7] which gives numerical values just twice as large as the values of brightness gain herein defined.

A screen which has an elongated polar distribution diagram, such as that represented in Fig. 1A, has a brightness gain which is greater than unity.  This type of screen is generally referred to as a *directional screen*.  A material having a flattened rather than an elongated polar diagram, like that shown in Fig. 2B, has a brightness gain which is less than unity;  such materials are seldom used for projection screens.

The brightness of a screen depends not only upon the illumination and the brightness gain, but also upon the reflectance or transmittance of the screen material.  A useful parameter for screen comparison is

the *effective brightness gain*, which includes the effect of reflectance, $R$, or transmittance, $T$, and is defined as,

$$G_{eff} = RG \text{ (for front projection screens)},$$
$$G_{eff} = TG \text{ (for rear projection screens)}.$$

*Choice of Screen Material*

The choice of a screen for use in a given situation depends on how the audience is distributed about the screen. The screen should direct as much light as possible toward the audience, and as little light as possible in other directions. A screen which is "tailored" to the audience will make the most efficient use of the available light from the screen.

It is evident that the vertical and the horizontal distribution diagrams of the screen need not be the same. A screen which confines the scattered light to the minimum vertical and horizontal angles consistent with the particular requirements will have maximum usable brightness gain. A screen with a lower brightness gain will not utilize the available light to the greatest advantage.

A screen which appears equally bright to all observers within the intended region of coverage of the screen and which has zero brightness to observers situated outside this region cannot be achieved in practice. Screen materials can, however, be chosen to approximate this condition reasonably well. Parameters which are useful in making such a choice are the horizontal and vertical angles of coverage. The brightness gain of a screen is related to these angles of coverage, usually defined as the angles between the directions in which the screen has half its maximum brightness.

It is frequently assumed that the light incident on the screen comes from a single well-defined direction. This assumption should, however, be used with care. In practice, the light incident on any point of the screen consists of a cone of rays coming from the projection lens aperture and converging at the point on the screen. Further, the rays falling on the edges and corners of the screen have a different angle of incidence than the rays at the center. In motion picture projection, the cone of rays converging at any point on the screen is very small, and the rays to opposite corners of the picture make a rather small angle with each other. Moreover, low brightness gain (wide angle) screens which closely approximate Lambert scatterers are generally used. Therefore, in motion picture practice, the assumption is valid. In television projection, on the other hand, the

angles involved are quite large and high brightness gain screens are generally employed. The range of angles of incidence of the light rays at the screen may be comparable to or larger than the angular width of the distribution diagram. When the incident convergent cone of rays is large, the effective distribution diagrams are broadened and the effective brightness gain is lowered, as shown in Fig. 3A. When the angle of incidence changes sufficiently over the screen area, the distribution diagram differs correspondingly for different regions of the screen. This generally will result in nonuniform brightness over the screen area, the effect becoming more noticeable at high brightness gain figures and at large oblique viewing angles. Curved
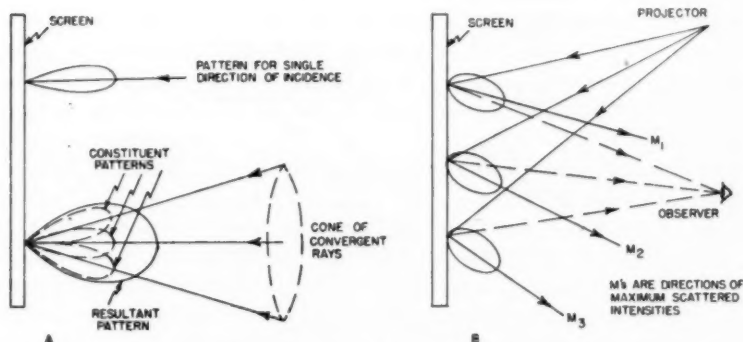


Fig. 3. A, diagrams illustrating the broadening of the intensity diagram that results when light is incident over an appreciable range of angles; B, illustrates the variation in relative brightness accompanying a variation in angle of incidence across the screen.

screens,[7] auxiliary optical elements such as a Fresnel lens,[11] nonhomogeneous screens, or other innovations may offer advantages in these cases.

### Experimental Equipment and Procedure

Of the various possible experimental procedures, the following was chosen as being the best adapted to measurement of small screen samples. A slide projector with a small circular aperture in the slide position projects a uniformly illuminated circular spot of light onto the screen sample. A visually corrected photronic cell, used as a detector, is mounted on an arm which can be rotated horizontally about the illuminated spot as a center. The illumination measured by the photronic cell is proportional to the candlepower of the ele-

mentary screen area. A polar plot of a series of measurements at different angles gives the horizontal intensity distribution curve. The screen sample can be rotated through 90° to obtain the vertical pattern. Figure 4 illustrates the apparatus. A known and fixed value of incident illumination is maintained by a line voltage regulator and a variac.

Initial calibration is performed with the lamp operating under known steady conditions. The total flux projected onto the illuminated spot is determined by removing the screen sample and allowing the light from the projector to fall on a large distant screen. The illumination on this large screen area is measured at numerous points
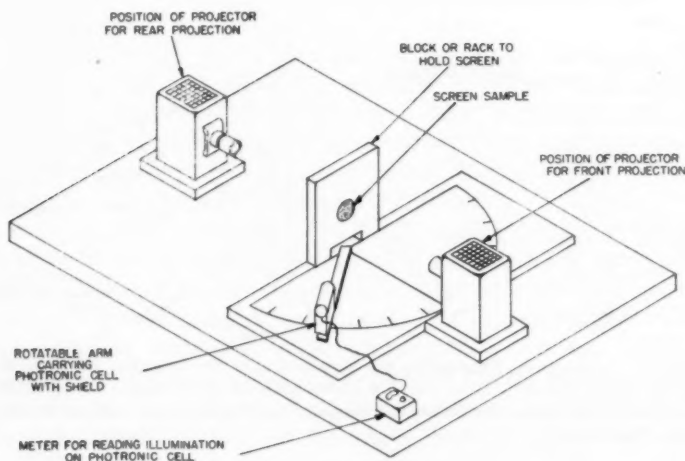


Fig. 4. Equipment used to determine screen parameters by the intensity method.

and total flux is determined by numerical integration over the entire area. This calibration method gives higher precision than can be obtained by measurements on the small, highly illuminated spot at the screen sample.

The light output from the projector may change after initial calibration due to aging of the lamp. To avoid the necessity for recalibration at frequent intervals, a series of measurements was made on a carefully prepared magnesium carbonate block. The pattern, brightness gain and reflectivity of the magnesium carbonate block were determined as accurately as possible. This block was then used as a secondary reference standard. Measurements with reference to the

magnesium carbonate were found to be satisfactorily reproducible and were in agreement with published values.    Therefore, as a standardizing procedure on subsequent tests, the lamp voltage was adjusted to give an arbitrary photronic cell reading with the magnesium carbonate standard.

Another experimental method was used for measurement of large screen areas.    In this case, the entire screen is illuminated with a projector and the screen brightness is measured directly, using a Macbeth illuminometer or an SEI (Salford Electrical Instrument) exposure photometer.    In order to calculate reflectance and to guard against variations in the source, screen illumination is monitored by use of a footcandle meter.

The first method, involving candlepower measurement, is convenient for laboratory use.   Its chief advantage is that only a small screen sample is required.    The incident illumination can be precisely controlled.    Further, the measurement is based on an electrical meter reading and is thus not subject to the human errors which may arise in visual photometry.

The second method, involving direct brightness measurement, can be used with large screen samples.    The portability of the equipment and the nature of the measurements permit use under actual field conditions, as in a theater.    The method is well suited for measurements at large angular departure from normal, where candlepower falls off very rapidly but brightness remains relatively constant.

Some screen samples were measured more than once, and were measured by both methods.    The consistency of the results leads us to believe that the brightness gain values are good to $\pm 5\%$ with the lower gain figures being somewhat more reliable than the higher brightness gain figures.    The reflectance values are likewise good to about $5\%$.    A series of measurements on magnesium carbonate by the candlepower method shows $\pm 2\%$ consistency.

*Experimental Results*

Table I gives the results of laboratory measurement on a number of screens and of several miscellaneous materials.    Some of the materials were measured by the intensity method and others were measured by both the intensity and the brightness methods.    All data presented refer to measurements made with incident illumination normal to the screen surface.    All of the screens are homogeneous, except the ribbed plastic screen with Fresnel lens;   measurements on the latter pertain to the central region only.    Some of the laboratory measurements are presented in Figs. 5 and 6.

## Conclusions

Certain optical characteristics of projection screens have been dealt with rather extensively. It is hoped that this discussion will help the reader to picture more clearly the fairly complex problem with which we are dealing and to comprehend the meaning of those few parameters which we have considered.

*TABLE I. Characteristics of Representative Screens*

| Screen | Brightness Gain, $G$ | Reflectance, $R\%$ | Transmittance, $T\%$ | Effective Brightness Gain, $GR$ or $GT$ |
|---|---|---|---|---|
| *Miscellaneous Materials* | | | | |
| Perfect screen | 1.0 | 100 | 100 | 1.0 |
| Magnesium carbonate | 1.1 | 88 | — | 0.97 |
| Traceolene paper | 13.6 | — | 87 | 11.8 |
| Opal glass | 1.0 | — | 48 | 0.48 |
| White blotting paper | 1.4 | 61 | — | 0.85 |
| Brushed aluminum | 4.5 | 65 | — | 2.9 |
| *Motion Picture Screens* | | | | |
| Smooth-surface plastic (perforated) | 1.15 | 72 | — | 0.83 |
| Beaded | 16.4 | 35 | — | 5.7 |
| Nylon cloth | 1.2 | 49 | — | 0.6 |
| Metallized directional (perforated) | 2.5 | 70 | — | 1.8 |
| Glass cloth | 1.7 | 47 | — | 0.8 |
| *Commercial Television Screens* | | | | |
| Translucent plastic #1 | 12. | — | 54 | 6.5 |
| Translucent plastic #2 | 6.2 | — | 62 | 3.9 |
| Diffusing cloth | 4.2 | — | 47 | 2.0 |
| Diffusing glass | 5.1 | — | 70 | 3.6 |
| Ribbed glass | 7.0 | — | 49 | 3.2 |
| Ribbed plastic with Fresnel lens | 8.0 | — | 43 | 3.2 |
| Metal beaded | 7.5 | 61 | — | 4.6 |

The experimental apparatus described and the procedure developed enable us to measure rapidly the more important optical characteristics of a screen material with an accuracy sufficient for most purposes. Measurements made on a number of motion picture screens, television screens, and other materials of interest, are believed to be accurate to within 5%. Our results are in reasonable agreement with the few published figures we have been able to find.

## Acknowledgments

The measuring procedure herein described was developed by G. M. Rentoumis and the author. Mr. Rentoumis also carried out many

of the laboratory measurements;　B. D. Plakun rendered editorial assistance.
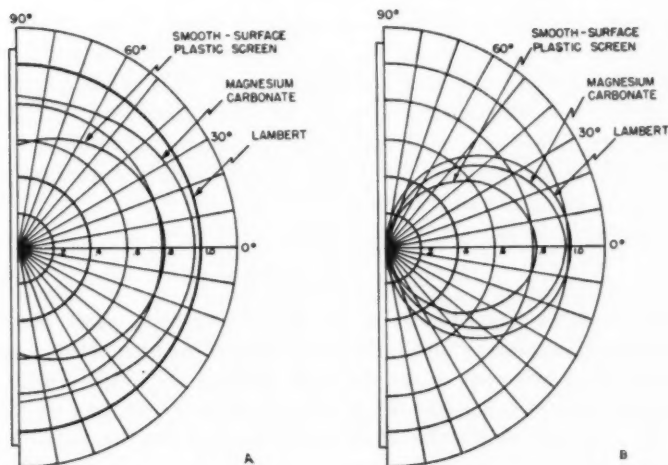


Fig. 5. Brightness and intensity patterns for a "perfect" screen (100% reflectance Lambert scatterer), the magnesium carbonate standard, and the smooth-surface plastic screen included in Table I. On the brightness diagram, A, the radial scale gives foot-Lamberts per foot-candle of illumination; on the intensity diagram, B, the radial scale gives candles per $\pi$ square feet of screen area per foot-candle of illumination.
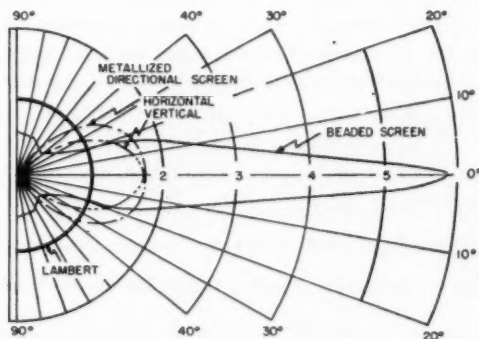


Fig. 6. Brightness patterns for a typical beaded screen and for a metallized screen. The pattern for a "perfect" screen is shown for comparison. The radial scale is graduated in foot-Lamberts per foot-candle of illumination.

## APPENDIX I

### *Derivation of Expressions for Brightness Gain and Reflectivity*

Brightness gain, $G$, has been defined as the ratio of brightness, $B_0$, of a screen, as observed in the direction in which it has maximum brightness, to the brightness $B_0{}'$ of a Lambert screen emitting the same total flux per unit area of screen surface.  From this definition and from basic photometric concepts we shall derive an expression for the brightness gain in terms of the brightness distribution curve of the screen.  Reflectance (or transmittance) will be expressed as a function of the gain and of other parameters.

From basic definitions, we may write,

$$dL = Cd\omega = B \, da \cos \Theta \, d\omega \qquad (1)$$

where $dL$ is the flux emitted in the elementary solid angle, $d\omega$, and where $C$ is the intensity and $B$ the brightness of the elementary source area $da$ when observed in the direction making the angle $\Theta$ with the normal to $da$.   A consistent set of units must, of course, be employed; e.g., $L$, $C$, $B$ and $da$ may be expressed in lumens, candles, candles per square foot, and square feet respectively.   The total flux emitted from the elementary source $da$ is then

$$L = \int dL = \int Cd\omega = da \int B \cos \Theta \, d\omega \qquad (2)$$

where the integrations are to be carried out over the entire solid angle on the observer's side of the plane containing $da$.

In general, the brightness of a given source will be a function of direction which is not necessarily symmetrical about the direction of maximum brightness.   That is, the brightness, $B$, must be expressed as a function of two variables, say the angles $\alpha$ and $\beta$, where $\beta$ is the angle between the direction of observation and the horizontal plane, and $\alpha$ is the angle between the normal to the vertical element of area $da$ and the projection of the direction of observation onto the horizontal plane.   It is convenient to express the brightness, $B$, in any direction as the product of the maximum brightness, $B_0$, by an angular dependence function, $g\,(\alpha, \beta)$, i.e.,

$$B = B_0 g(\alpha, \beta). \qquad (3)$$

In terms of the co-ordinates $\alpha$ and $\beta$ it can be shown that,

$$\cos \Theta = \cos \alpha \cos \beta \qquad (4)$$

and that the element of solid angle can be expressed as,

$$d\omega = \cos \beta \, d\alpha \, d\beta. \qquad (5)$$

Substituting Eq. (3), (4) and (5) into (2), we can now express the total flux as,

$$L = da \int B \cos \Theta \, d\omega = B_0 da \int_{-\pi/2}^{\pi/2} \int_{-\pi/2}^{\pi/2} g(\alpha, \beta) \cos \alpha \cos^2 \beta \, d\alpha \, d\beta. \quad (6)$$

Now, a Lambert source, by definition, has a brightness independent of the direction of observation; i.e., $g(\alpha, \beta)$ is a constant equal to unity. Setting $g(\alpha, \beta)$ equal to unity in Eq. (6) and evaluating the resulting simple integral gives for the total flux, $L'$, from a Lambert source of area $da'$ and of brightness $B_0'$,

$$L' = \pi B_0' \, da'. \quad (7)$$

Returning now to our definition of brightness gain, we see that it is expressed by the ratio of $B_0$ to $B_0'$, subject to the condition that $L/da = L'/da'$; hence from (6) and (7) we get the desired expression

$$G = \frac{B_0}{B_0'} = \frac{\pi}{\int \int g(\alpha, \beta) \cos \alpha \cos^2 \beta \, d\alpha \, d\beta}. \quad (8)$$

We could follow through a similar argument in which attention is focused on the intensity distribution rather than the brightness distribution. We would then find it convenient to define an intensity angular dependence function $f(\alpha, \beta)$ by

$$C = C_0 f(\alpha, \beta) \quad (9)$$

analogous to Eq. (3) and our resultant expression for brightness gain would be

$$G = \frac{\pi}{\cos \Theta_0 \int \int f(\alpha, \beta) \cos \beta \, d\alpha \, d\beta} \quad (10)$$

which is equivalent to Eq. (8) and wherein $\Theta_0$ is the angle between the normal to $da$ and the direction of maximum brightness.

The reflectance of a screen is defined as the ratio of the total reflected or scattered flux, $L$, to the incident flux, $L_i$. The scattered flux is given by Eq. (6) and the incident flux may be expressed as

$$L_i = \int E \, da \quad (11)$$

where $E$ is the illumination on the screen and the integration extends over the total area under consideration. If we assume that $E$ is uniform over this area, the integral sign may be dropped and $da$ has the meaning previously assigned. Using Eq. (6) and (8) we may write,

$$R = \frac{L}{L_t} = \frac{B_0}{E} \int\int g(\alpha, \beta) \cos\alpha \cos^2\beta \, d\alpha \, d\beta = \frac{\pi B_0}{EG} \quad (12)$$

where $B_0$ is expressed in candles per unit area and $E$ is in lumens per unit area.   If the maximum brightness is expressed in foot-Lamberts and the screen illumination is expressed in foot-candles, expression (12) becomes

$$R = \frac{B_0 \text{ (ft-L)}}{E\text{(ft-c)}} \frac{1}{G} . \quad (13)$$

It follows from this expression that the maximum brightness in foot-Lamberts divided by the illumination in foot-candles is numerically equal to the effective brightness gain, $G_{\text{eff}} = RG$.   Equations (12) and (13) give, of course, the transmittance, $T$, rather than the reflectance, $R$, in the case of rear projection screens.


## APPENDIX II

### *Treatment of Experimental Data*

The experimental procedures described enable one to obtain a series of values of intensity or of brightness measured in different directions; i.e., to obtain $C_0$ or $B_0$ and the values of $f(\alpha, \beta)$ or of $g(\alpha, \beta)$ for certain values of $\alpha$ and $\beta$.   In order to determine the brightness gain and reflectance (or transmittance) from these data it is necessary to evaluate the integrals occurring in Eq. (8) or (10).   Although it is possible to fit the observed data with analytic functional representations of $g(\alpha, \beta)$ and $f(\alpha, \beta)$ it is generally more satisfactory to approximate the integrals by numerical methods.

Experimentally it is convenient and generally adequate to make measurements in the horizontal and vertical planes only, i.e., to determine $f(\alpha, 0)$ and $f(0, \beta)$.   Let us use the notation $f(\alpha, 0) = H(\alpha)$ for the horizontal intensity pattern, and $f(0, \beta) = V(\beta)$ for the vertical intensity pattern.   If $\Theta_0$ is small, very little error is introduced by making the approximation,

$$f(\alpha, \beta) = H(\alpha) \, V(\beta) . \quad (14)$$

For simplicity, we shall assume further that the patterns are symmetrical and that $\Theta_0 = 0$, whence from Eq. (10),

$$\frac{\pi}{G} = 4 \int_0^{\pi/2} H(\alpha) d\alpha \int_0^{\pi/2} V(\beta) \cos\beta \, d\beta. \quad (15)$$

Approximating the integrations by summations and expressing the angles in degrees we have,

$$\pi/G = \frac{4}{(57.3)^2}\left\{\sum_j H(\alpha_j)\,\Delta\alpha_j\right\}\left\{\sum_i V(\beta_i)\,\cos\,\beta_i\Delta\beta_i\right\}$$

$$= 4\,\frac{\Delta\alpha\,\Delta\beta}{(57.3)^2}\left\{\sum_{j=1}^{n} H(\alpha_j)\right\}\left\{\sum_{i=1}^{m} V(\beta_i)\,\cos\,\beta_i\right\} \tag{16}$$

where $\Delta\alpha = 90°/n$, $\Delta\beta = 90°/m$, $m$ and $n$ are any integers, and where $\alpha_j = \Delta\alpha/2 + j\Delta\alpha$ and $\beta_i = \Delta\beta/2 + i\Delta\beta$.

In the more general case where the patterns are asymmetrical and where $\Theta_0$ is not equal to zero, suitable numerical expressions superseding (16) can be developed by similar arguments. The brightness gain may be computed arithmetically after direct substitution of the observed data into Eq. (16) or its counterpart.

It might be noted that in using apparatus of the type illustrated in Fig. 4, the directly measured quantity is the illumination, $E_d$, falling on the detector. The intensity $C$, in candles, of the illuminated spot is simply

$$C = E_d r^2 \tag{17}$$

where $E_d$ is in lumens per square foot (foot-candles) and $r$ is the constant distance from the screen sample to the detector expressed in feet. Equation (12) for the reflectance (or transmittance) becomes, then, in terms of the directly measured quantities

$$R = \frac{L}{L_i} = \frac{\pi B_0}{EG} = \frac{\pi}{EG}\,\frac{E_d r^2}{da} \tag{18}$$

where $E$ is the illumination on the sample of area $da$.

If the direct observations are of brightness rather than of intensity, one may compute $H$ and $V$ from the relations

$$H(\alpha) = g(\alpha, 0)\,\cos\,\alpha \tag{19a}$$

$$V(\beta) = g(0,\beta)\,\cos\,\beta \tag{19b}$$

and then use Eq. (16). Reflectance (or transmittance) may be calculated directly from Eq. (12), necessitating, of course, a measurement of the screen illumination, $E$.

The integral appearing in Eq. (10) may be thought of as the effective solid angle occupied by the scattered light. For moderately or highly directional screens this solid angle is roughly equal to the

product of the vertical and the horizontal angles of coverage, $A$ and $B$, expressed in radians. Thus, a rough approximate expression for the brightness gain is

$$G = \frac{\pi}{AB \cos \Theta_0}. \tag{20}$$

It is found by trial and error that the approximation is best if $A$ and $B$ are defined as the angles between the directions in which the intensities have fallen to one-third of their maximum values.

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# Specifications for Motion Picture Films Intended for Television Transmission

By CHARLES L. TOWNSEND

NATIONAL BROADCASTING CO., NEW YORK, N.Y.

SUMMARY: Consideration is given to the major problems encountered in television reproduction of motion picture film. Present practices are discussed and special requirements of the television system are described. The qualities presently desirable in a motion picture film to fit it to that system are defined, along with explanatory exposition. An appendix lists the specifications for quick reference.

MANY YEARS of motion picture theater viewing have established a reasonably well understood norm for motion picture quality. When such motion pictures are transmitted by a television system it is presumably desirable to reproduce them with a quality as near that norm as the state of the art permits. It is not desirable to demand new end-result standards, or to require major changes in production techniques. It is pointed out, however, that both the film and the television system have inherent technical degradations, which are compounded in the final result. This discussion is directed toward defining those properties which a film image should exhibit for television use, while still retaining as much as possible of the established motion picture characteristics.

The problem is divided below into considerations of gray-range or transfer characteristic, detail rendition or resolution, and scene content effects.

## I. TRANSFER CHARACTERISTIC

### 1. Pickup Equipment

Almost all television stations now use iconoscope tubes for film transmission. Under the intensive programs of research directed toward development of new television pickup devices it is possible that superior film transmission systems will become available in the future. For the present discussion, however, iconoscope transmission will be assumed.

### 2. Characteristics of the Television System

Special projectors are used for television as a means to change from the sound film frame rate of 24 per second to the television frame rate

of 30 per second.    Alternate film frames are scanned three times, as against the others, which are scanned twice.    This difference in handling does not alter the action on the film since the average rate of film travel is still the original 24 frames per second.

The projectors use a very short pulse of light, which can be supplied by a gap lamp without a shutter, or by an incandescent, or arc lamp with a rotating shutter having a very small open period.    The shortness of the open period causes a severe light loss, so that only enough light is obtained for a small picture even though a lamp normally intended for large-screen viewing is used.    This effect has a large influence on the maximum film densities usable, and upon the "noise" or graininess of the television system.

The iconoscope pickup tube has a screen which consists of millions of small photocells deposited upon a nonconducting film supported by a metallic plate.    The photocells "see" the picture for a short period, and then are scanned in the dark.    They must have good memory or "storage" if they are to supply good contrast over the whole plate.    Also, their small-area sensitivity is influenced by adjacent area illumination, so that spurious signals are generated, which are only distantly related to the original scene content.    These signal voltages must be balanced out by adding to them other oppositely "shaped" voltages, which constitutes the operation of "shading."    In general, more shading is required when dark scenes are televised, and when large black areas are located near a frame edge.    The latter case usually produces "flare," or a tendency for the black to "bleed off" to gray.    Flare is an effect which can be reduced by proper film density control.

System "noise level" or electrical graininess* is also important in picture quality.    It is inevitable that the electronic system should produce noise when the signals incoming are low.    The amount of noise is determined to a great extent by the amount of amplification which must be used.    A low signal, whether it be due to a dark film or a low sensitivity iconoscope, will require more-than-usual amplification and the picture will be noisy.    This system "noise grain" is important in determining the effects of excess density and graininess in the photographic image.

* Noise level at any point in a transmission system is the ratio of the circuit noise at that point to some arbitrary amount of circuit noise chosen as a reference.    This ratio is usually expressed in decibels above reference noise, abbreviated dbrn, signifying the reading of a circuit noise meter, or in adjusted decibels, abbreviated dba, signifying circuit noise meter reading adjusted to represent interfering effect under specified conditions.—From ASA C42 "American Standard Definitions of Electrical Terms."

Measurements of the transfer characteristic of iconoscopes indicates that when the above-mentioned effects of storage, shading and grain are properly controlled, the tube's output voltage is an almost linear function of film density over an appreciable range. This television system gray-range is important to the film manufacturer because some films permit a wider range of tones than does the electrical system. Attempting to compress a wide-range picture into a television system must result in the appearance of the effects of electrical "toes and shoulders," analogous to characteristics of film emulsions shown by the conventional H & D curves. The transfer characteristic encountered looks much like that of ordinary films, in that it is generally S-shaped, exhibiting a fairly sharp toe and a more round white-range shoulder. There is a reasonably linear central portion of the curve; but, if only that portion is used in reproduction, insufficient output voltage is generally obtained, increasing the electrical noise level beyond acceptability. Thus it becomes imperative to use as much as possible of the iconoscope characteristic, even though some compression is encountered.

Problems of compression are somewhat complex. If a completely compression-free scene is thrown on the plate of an iconoscope (as in the case of live pickup), the characteristic toe and shoulder are not excessive. Through long education most observers have come to expect and even demand controlled range compression. Such compression is valuable in reducing sudden brightness changes between scenes, and to permit presentations of scenes which if fully reproduced would be painfully bright or so dark as to lose all information. However, if a scene is televised which already has a normal amount of compression, then that compression and the system compression are cumulative, and the result is unsatisfactory. If a film is so made that every bit of acceptable toe and shoulder is already present, it would have to be reproduced on a toe-and-shoulder-free system. Our present television systems do not have that characteristic.

The effects of a change in exposure or development of a film are apt to be obscured when that film is reproduced on a television system because video controls permit easy change of contrast and average brightness. Some effects which will appear similar to gamma changes produced by variations in film processing can be obtained by electrical compressions, which can be introduced particularly well in the black signal range. Special equipment permits controlled bending of the electrical system transfer characteristic to expand the white signal range almost at will. Both "amount" and "break point" of such bending can be adjusted to suit an individual case. It is, how-

ever, inadvisable to depend too much upon such compensation, since the steep gradients required for large effects cause the electrical system to become "wild" and difficult to operate. In general, films should be made to have as little compression in their significant densities as the state of the art will permit. In this way only small compensations will be required, and good operational performance can be expected.

### 3. Film Characteristics

There is a real desire on the part of most film producers to make their product fit the needs of the television system. Many have asked for complete specifications for television films in the hope of obtaining inflexibly correct values and procedures. The information below will serve to define as far as possible these correct values and procedures, but will also indicate why they cannot be inflexibly specified.

*Density range* is the most important aspect of the television film. To provide good signal-to-noise ratio, the film must transmit as much light as possible. To stay within the tone-range of the system no more density range should be recorded than is expected to be reproduced. The numerical values of these limitations may be stated fairly firmly. The usual iconoscope tube can accommodate a density range of approximately 1.5. That is, the light energy in the high-lights should not exceed 32 times that in the darkest portions to be reproduced. Actually, a somewhat greater range can be transmitted, but only with excessive compression effects. The position of the 1.5 density range in the film characteristic is also important. With present projection illumination levels, the minimum significant density should not be greater than 0.4 if good signal-to-noise ratio is to be obtained. That is, maximum important high-lights should be placed approximately at 0.4, with some "white peaks" extending below this value only if they have little or no importance in the scene, or if no detail is present in them. The major reason that lower densities are not valuable lies in the fact that most films show compression effects in that range. Print characteristic curvatures between the densities of fog level and 0.4 are usually too great to be tolerated by a system which increases that curvature. Of course, there are printing systems which depend upon a balance between a long curved negative characteristic and a complementary print curve. In this case, the above statement may require modification, but it is believed that very little printing is done in this manner. When "normal" printing is used, best results will be obtained if the significant densities are placed in the range from 0.4 to

1.9, with only unimportant areas or areas lacking detail permitted to fall outside these limits. In cases where large black areas must appear at the bottom of the frame or where black backgrounds are required for short periods of time, a further reduction in density of these black areas is recommended. A maximum density value of 1.5 in these areas is more appropriate if flare and the resulting bleeding of the black are to be held to a minimum. Ordinarily such a background will be reproduced as black on the television system, since the original intention will be obvious to the video operator.

Many film producers have requested specifications on film stocks and development gammas rather than a required range of densities. It has not been possible to make any firm statements of this type for the following reasons:

Gamma is the parameter for which most specification requests are received. Without any information other than the question, "What gamma is best for television films?" no answer can be given at all. The term "print gamma" usually refers to the value of the slope of the density vs. exposure curve for a particular stock developed under some particular conditions. Usually it is read at the high-density end of the curve. When this is done an excellent measure of the effects of development is obtained, but with very little information concerning the appearance of the picture. As a tool for processing control, print gamma is excellent, but the picture density range is usually not "read." Thus two films may be handled so that their IIB densities may be plotted as straight lines from values of 1 to 2.5, but exhibit entirely different characteristics below that range. They would both have the same "gamma," as far as quoting a number is concerned, making such a quote an extremely unreliable basis for judging picture quality.

Again, if a negative is low in contrast, a higher print gamma is required than if it were "normal." Both of these conditions can produce good pictures, as can the case for a high contrast negative and a low gamma print. Obviously, some knowledge of the negative development would be required for print gamma specification.

"Print-through-gamma" is also an elusive quantity. Curve slopes are never read in the actual picture range, especially since evaluation of gradients in that range is difficult. The net result of combining two gammas is dependent, therefore, on the curve shapes, as well as the exact portions of those shapes actually used. Even when a producing company has arrived at standard developments for negatives and positives, the assignment of a particular print-through-gamma is dangerous because of variations in the original scene contrasts and in negative exposure.

Most film that is good for television use has employed a restricted scene brightness range. This does not mean "flat" studio lighting. All the accent lighting used so effectively by Hollywood can and should be retained. But the ratio of that light to fill-light must be reduced. Again it becomes a problem of fitting the scene into final print densities which can be faithfully reproduced. If it is judged that for a particular scene the brightness ranges that are high in value are the most important, then it may be that large values of back-light and high-light can be tolerated, and the densities representing these brightnesses must be printed within the range. But if it is judged that for another scene the low-value brightnesses are most important, then high-lights must be sacrificed, and exposure increased to get the print densities down within the specified range. If 100- or 200-to-1 films are made, only disappointment can result from compressing them into a 30-to-1 channel.

Many television films are made outdoors with enormous scene brightness ranges, and yet produce excellent results. Some of these films actually show a print density range of 3. This case is a good example of the above reasoning. If the wide range film is mostly small detail of trees, rocks, etc., the video signal will show no texture in the blacks or whites, but none is needed, since these areas are "texture" in themselves. As soon as a medium shot or close-up requires detail in light or dark areas, those areas must be protected from compression by placing them within the specified range. If the large range is maintained, faces will become blank white, and dark horses become animated charcoal drawings. Judicious use of reflectors or fill-light of any kind will reduce the range of most outdoor close-ups to permit the adjustment of exposure to produce the densities required.

From the above it will be seen that many combinations of negative gamma and print gamma can be made to yield good pictures, depending upon the control exercised in original scene brightness range and exposure. The final product is a range of densities, which has been specified; and the means by which an individual producer arrives at those values is largely a function of his own operating conditions.

## II. RESOLUTION

### 1. Television System Characteristics

The television picture delivered to the home viewer is limited in resolution by the bandwidth specified by the Federal Communications Commission, and by the performance of the equipment utilized. In general, acceptable sharpness is obtainable under normal circum-

stances. Several studies have been made to determine just how sharp a picture can be broadcast in the present television channel. Tests with photographic methods whereby an ideal television system can be simulated, and the use of actual television equipment of a highly refined type, have both shown that present system standards can deliver truly excellent definition. That such results are not always attained can be attributed to the large number of system elements which are difficult to control. Some of these are discussed below.

Under normal circumstances the amplifiers and circuits of the television system impose no limitation on the transmission of fine picture detail. Pickup tubes, however, can exert a large effect on final picture sharpness. Ideally, such a tube should have full video voltage output at the highest frequency utilized. That is, the finest black-and-white detail to be transmitted should produce as much signal voltage as does any larger area. Present-day pickup tubes do not completely fulfill this requirement, having a reduced output level at the frequencies corresponding to fine detail in the picture. Electrical equalization is used to compensate for this effect, but this increases the fine-grain "noise" in the transmitted picture so that large amounts of compensation are not desirable. Great care must be exercised to see that the pickup tube is supplied with the best possible picture, in order that over-all degradation is kept to a minimum, since any degradation in the picture will be compounded with degradation in the television system.

Suppose for a moment that an audience will accept without comment a well-defined maximum loss in picture detail at a certain viewing distance. If a television picture having that loss is viewed in that manner, acceptable results are obtained. If a film picture having that loss is viewed in that manner, acceptable results are also obtained. However, if that film, which is acceptable, is viewed over that television system (which in itself is acceptable) seriously degraded and unacceptable pictures will result. Neither picture system in itself is bad, but the combination of the systems adds their individual losses, and the result is noticeably poor.

This introduces the idea that each element of a picture transmission system must be assigned its appropriate part of the total permissible loss. Each such loss must be as small as the state of the art permits. Good circuit design has reduced amplifier losses to a negligible value, but the enormous complexity of picture tube design and construction has not permitted attainment of that degree of perfection in their operation. It has thus long been good practice to assign the major portion of the total permissible resolution loss to the pickup tube. A

great deal of research is being devoted to reducing this loss but for the present it is well to continue to "pamper" the pickup tube.

In live-studio practice it is fairly usual for optical systems to deliver to the pickup tube photo-cathode images having limiting resolution in excess of one thousand television lines. Under such circumstances very little degradation is contributed by the optical image, and the net effective sharpness is that of the picture tube. With film, however, projected image resolution rarely reaches such a high value, and the net effective sharpness is below that of the pickup tube alone. It is interesting to note that live-studio pictures are noticeably degraded when the optical resolving power drops below 800 television lines.

Further complicating the resolution problem is the electrical grain or "noise" inevitable in present systems. If pictures having small "signal" content (low density range) are fed to such a system, amplifier gain must be raised beyond normal limits to regain normal operating levels. This increases the effect of noise, masking the fine detail in much the same manner as does the grain in a poorly made photograph.

Kinescope picture viewing tubes also are pertinent in a discussion of resolution. Good tubes having fine spots are available, but generally some loss should be allowed for this device. An effect called "blooming" is particularly important in film reproduction. Whenever an excessively wide gray-range is fed into the television system, very bright white areas are likely to produce high signals which are well above the general "tone" of the scene. In order to reproduce the lower signals properly, the voltages must be amplified more than usual before being fed to the picture tube. In this case the bright white signals are too high in level for normal operation and those areas blur, losing line structure and picture texture. A reasonable balance between "whites" and "blacks" is desirable for maximum sharpness.

## 2. Film Capabilities

Having established the resolution needs of the television system, it becomes possible to define the performance required of film systems designed for its use. Again, some portion of the total permissible resolution loss must be assigned to the photographic medium. But every effort must be made to match the live pickup sharpness, which means that very little loss can be so assigned. Photography is an old, established craft capable of excellent image sharpness, so it seems

reasonable that stringent requirements should be placed upon it, leaving more leeway for the infant television art.

Quite often it is said that film has such excellent resolution that there cannot be any problem in its television use. Published values of limiting resolution for many films seem to confirm this, but a closer investigation indicates differently. First, it must be remembered that the film resolving-power ratings are for "cutoff" conditions. That is, they state the highest value at which any line structure can be seen. This, of course, is at a very *low* contrast—far too low to be of any value to the television system. "Contrast" is "modulation" in the electrical system, and it is possible to plot the response of film in much the same manner as an electrical system. When this is done, it is discovered that films have no "flat bandwidth." That is, their contrast falls off as the size of the elements to be resolved decreases. If the total photographic system is allowed about 10% loss in contrast at the maximum television resolution, it is found that its limiting resolution value must be well above the television cutoff. As a result of this, the best 16-mm films will be found to be barely good enough. As a matter of practical fact, it is exceedingly difficult to realize a resolution of 400 television lines with a high value of contrast in an ordinary 16-mm release print. Such a print includes degradations due to all the elements of the photographic system, including the effects of printing. For the present, only the very best products and techniques can be combined to produce a 16-mm print which will not seriously limit the results obtainable through the television channel. Whenever feasible, 35-mm film should be used, and in this case also, the best methods should be followed. Unfortunately, not all television stations are equipped to transmit 35-mm film, but if original shooting is done in that size, good quality can be expected from most of the larger stations, and the rest can be served by reduction-printed 16-mm versions.

### III. SCENE CONTENT

#### 1. Reproduced Area

Reference is made to the *Television Test Film* of the Society of Motion Picture and Television Engineers. The projector alignment section of that film includes an implied standard definition of the area to be scanned. Many stations now have copies of this film, and it is believed that following its directions will lead to satisfactory results. Approximately $1\frac{1}{2}\%$ of the standard projector frame is cut off in scanning at the top and bottom of the frame, and the sides are cut by

an amount required to maintain the 3 × 4 aspect ratio specified by law.  The side losses are not the same for 35-mm film as for 16-mm film, due to the different film frame aspect ratios.

Alignment chart sections from the 35-mm and 16-mm versions of the test film can be purchased separately, thereby reducing costs. Frequent reference to these charts, along with the instruction book accompanying them, is recommended.

Also included in the above chart is a rectangle enclosing approximately 65% of the frame area.  The lines forming it are placed so as to produce a 10% border within the televised frame.  The area within the rectangle is believed to be reasonably well reproduced on the home receiver even when scanning is poorly adjusted and centering is badly set.  Important information should be kept within this area, especially commercial copy titles or trade-marks.

### 2. "Busy" Scenes

Care should be taken to insure that a scene being photographed does not have a high-contrast background that will detract from foreground action when the picture is viewed on a small screen. Simplicity seems to be required in backgrounds for television more than for theater use, where images are not "crowded" by the frame size.

### 3. Shot Sizes

Television has long made good use of close-ups and medium shots. Small screen sizes are not the only reason for this.  The resolution needed for a close-up is less than for a long shot, merely on the basis that less fine detail is needed to carry the intended information. Thus, receiving sets which are mis-tuned or are out of focus will reproduce close-ups when long shots will be hopelessly blurred.

The above is not intended to eliminate long shots.  Establishing locale and impressions of size are as important as in the theater, but important details of wide-angle shots should be pointed up with clever accent lighting and reduction in unimportant competing detail.

### 4. Scene Tone Balance

Some refinements in smoothness of reproduction can be obtained when large black-and-white areas are needed, if they are used with care.  Half-black, half-white pictures, with the dividing line running horizontally, usually require relatively large shading corrections. This is particularly true if the lower half of the picture is black.  Sea-

scapes or any sky and land scene can fall into this category if no large foreground objects are available to break up the pattern. Also, sudden large changes in scene brightness should be avoided, as they place severe requirements on both transmitter and receiver "d-c insertion" performance. Smooth changes or small steps are usually reproduced without trouble. Cutting between shots of an object which have radically different background brightnesses can cause the object itself to appear to change tone, becoming darker with the light background, and lighter with the dark background. Avoid if possible the use of full daylight shooting of night scenes when the required effect is produced by purely photographic means. "Blacks" look severely compressed in that case, and video operators tend to raise their brightness control to bring out what may be there, but is not. If possible, always include some full-level high-light to define the "white signal" limit. Usually this can be done without harming the scene mood for direct projection and will greatly aid in television transmission.

## Appendix: Recapitulation of Specifications

1. *Density.* Normal contrast range, 1.5; minimum density, 0.4; and maximum density, 1.9.
2. *Gamma.* No exact statement possible, but generally the above will require that gamma be somewhat lower than usual in films intended for theater use.
3. *Resolution.* Limiting value, minimum, 800 television lines.
4. *Scene content*
    Follow: SMPTE frame-size specifications in the Television Test Film.
    Avoid: Sudden large brightness changes, large black areas near frame edges, "busy" backgrounds, too great gray range, artificial night shots.

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# A 100,000,000 Frame Per Second Camera

By M. SULTANOFF

Terminal Ballistic Laboratory, Aberdeen Proving Ground, Md.

SUMMARY: Shock waves close to the edge of explosive charges have been successfully photographed at rates exceeding 100,000,000 frames/sec. These ultra high framing rates are obtained with a multi-slit focal plane shutter which is transported optically across the film plane by a rotating mirror. Linear shutter speeds up to 3,000 meters/sec are easily obtained, and the resulting framing rates with the proper selection of slit widths can be varied from $10^5$ to $10^9$ frames/sec. Each individual frame is composed of a series of lines, and the degree of "discontinuity" across each frame is proportional to the total number of frames.

THE EXPERIMENTAL STUDIES of the shock and detonation which accompany explosive reactions have been hampered by the lack of ultra high-speed instrumentation. Short duration optical studies are particularly required for the investigation of self-luminous detonation and shock waves.

The velocity of these transients averages about 8 mm per microsecond; therefore, usable photographic exposures of these transients must not exceed $10^{-7}$ sec. Kerr cell shutters[1] have been used to obtain a single or a few successive short duration exposures, while multi-lens cameras[2] have produced continuous short duration exposures, but at rates which are not adequately high. The O'Brien-Milne camera,[3] which is rated at 10,000,000 frames/sec, but which displays poor resolving power, could not be obtained commercially, and its precise optical system made it impractical to build locally.

A motion picture camera which employs simple optical and mechanical systems to obtain up to 300 successive 4 × 4 in. frames at rates which can be varied from $10^5$ to $10^9$ frames/sec, and which exhibits satisfactory resolving power, is described in this paper.

## THEORY OF GRID FRAMING

The standard variable slit focal plane shutter in common use exposes a time–space record as it travels across the film plane. Although the slit moves slowly across the film, the exposure time can be made extremely short by reducing the width of the slit.

The framing grid is a focal plane shutter with a series of parallel slits placed at regular intervals across it. This shutter, therefore, is required to move only the distance between two successive slits to expose the entire film. To understand how this grid records successive frames, consider a series of optically clear slits .0005 in. wide, cut at .015-in. intervals across a $4 \times 4$ in. optically opaque plate. If this grid is held in a fixed position on a $4 \times 5$ in. photographic plate,
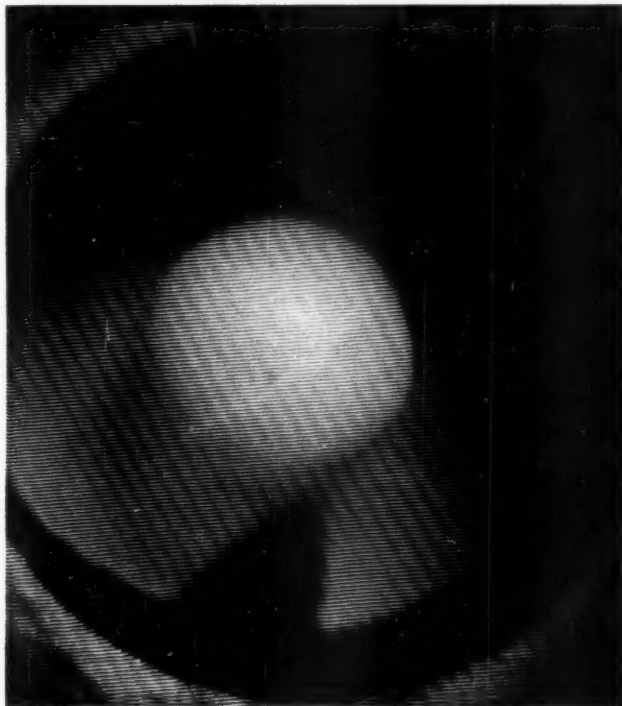


Fig. 1. Single still photograph of spherical charge in firing
position, taken through .0005-in. slit, .015-in. space grid.

a single exposure made through it would consist of a set of parallel lines which occupy only $\frac{1}{30}$ of the total picture area with an over-all dimension of $4 \times 4$ in. A sample exposure of this type is shown in Fig. 1. By moving the grid across the film perpendicularly to the slits for a distance of .0005 in., and exposing a second still picture in this new position, a second series of lines lying alongside the first set and again occupying only $\frac{1}{30}$ of the total picture area will be pro-

duced.    Thirty such single pictures will result from only .015-in. move-
ment of the grid, and will expose the entire film area.    To the casual
observer the resulting picture will be an indistinguishable jumble.
However, by proper positioning of the grid, any one of the 30 ex-
posures can be studied separately.    This type of grid framing has
been used for years in animated greeting cards and photographic ad-
vertisements.

If the photographic object is moving, and if the grid is moved at a
uniform rate across the film for a distance of .015 in., the resulting
picture can be viewed through the grid as 30 separate exposures, one
at a time, or, by viewing through the grid moving at any uniform
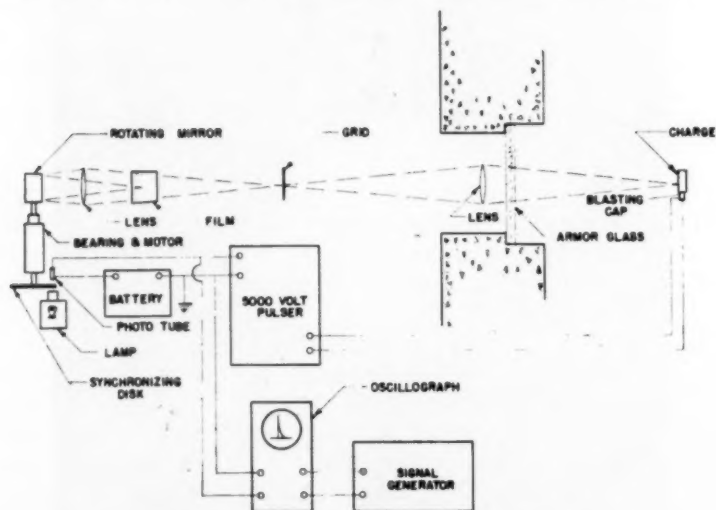


Fig. 2. Synchronizing circuit for ultra high-speed camera.

speed, flickerless motion pictures will be observed.    This adaptation
of grid framing has been described in papers delivered by Dr. Fordyce
Tuttle of the Eastman Kodak Co.[4]

At this laboratory we have been successful in combining a stationary
framing grid with a rotating mirror to obtain framing rates in excess
of $10^8$ frames/sec.

## The Rotating Mirror Grid Combination

The optimum slit width for the multi-slit focal plane shutter ap-
pears to be of the order of .0001 in.    A shutter with .0001-in. slits
is required to move 10,000 in./sec to produce $10^8$ frames/sec.    It is

impractical to accelerate to, maintain, and decelerate from, such high velocities with a linearly moving shutter. A rotating focal plane shutter, on the other hand, has the double disadvantage of requiring tapered radial slits and the combination of a large diameter and high rotational velocity. A method for moving the image of the shutter across the film plane by reflection from a rotating mirror was obviously a simple solution to this problem. The rotating mirror optical system in a Bowen RC-3 Rotating Mirror Camera,[5] although not adequate for this application, was available at this installation, and it was modified to take a $4 \times 4$ in. multi-slit framing grid and a $4 \times 5$ in. camera back.

A first lens is used to image the event on the grid. The combine event-grid is then focused by a second lens, whose image, after reflection from the rotating mirror, falls on the film plane as shown in
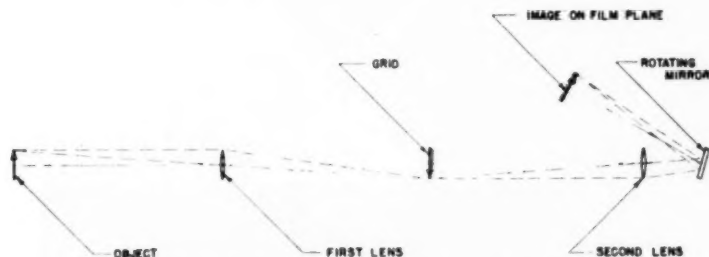


Fig. 3. Optical system of ultra high-speed camera.

Fig. 3. The photograph formed by the reflected grid differs from that formed through a grid moving across the film plane in that the latter records a varying-time–varying-space image, while the former, by virtue of the subject's fixed position with respect to the grid, records a fixed-space–varying-time record which is particularly suited to the studies of detonation and shock waves.

## Framing Rate

The continuous motion of the image across the film does not form the well-defined frame of the intermittent or the rotating prism type of cameras. An infinite number of viewing positions of the framing grid are possible, leaving the framing rate undetermined. However, since the exposure time of any increment of film is equal to the time it takes a slit to move its own width, the reciprocal of this time is taken as the framing rate. Thus, each consecutive frame is viewed by moving the grid one slit width per frame.
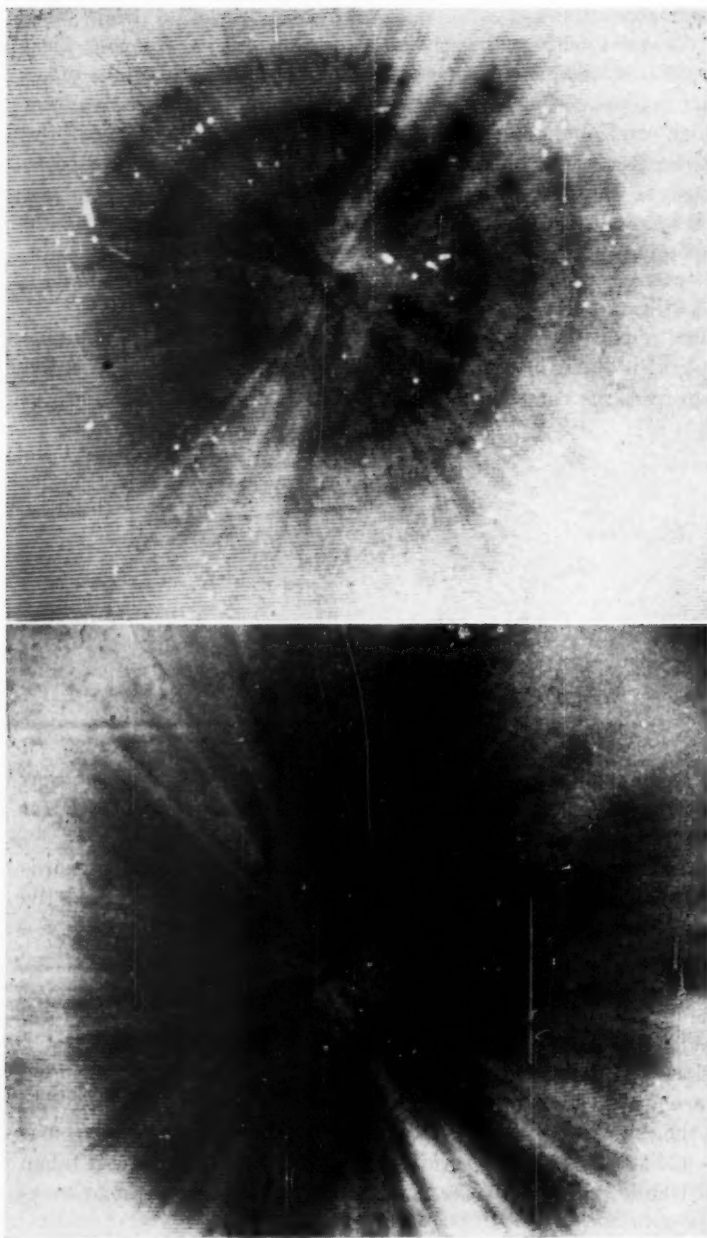
Fig. 4b. Single frame taken from Fig. 4a; negative; framing rate $1.1 \times 10^8$ frames/sec



Fig. 4a. Complete exposure of detonating spherical charge; negative.

The rotational speed of the mirror being used can be varied up to 500 rps; with a 20-in. optical arm the maximum image speed is .122 in. per microsecond. The exposure time with a .0005-in. slit at the full rotational speed of the mirror is $4 \times 10^{-9}$ sec, or $2.5 \times 10^8$ frames/sec. With a .0001-in. slit the framing rate is $1.25 \times 10^9$ frames/sec. With suitable optics, it is believed that sufficient light will be available from detonation and shock phenomena to take pictures at the rate of one billion frames per second.

<div align="center">

### The Contribution of the Grid to the Resolving Power and Total Number of Frames

</div>

The resolving power, or more exactly, the measure of the "discontinuity" across the picture because of the nature of its line structure, expressed in lines per inch, is equal to the number of slits per inch. The number of slits per inch is determined by the slit width and the number of frames required. That is, with a .0005-in. slit if 30 frames are desired, the space between the slits must be 30 times .0005 in. or .015 in. Such a grid will have a "resolving power" across the slits of $1/.0005 + .015$ or about 65 lines/in. With a .0001-in. slit and the same resolving power, 150 consecutive frames are obtainable.

The total exposure time, with no double exposures, is the product of the exposure time per frame and the total number of frames without double exposures. With 30 frames taken at 100,000,000/sec, the total exposure time is $3 \times 10^{-7}$ seconds. All of the pictures taken up to the present time have been of self-luminous shock waves. Double exposures are prevented by quenching the shock wave in an atmosphere of propane at a predetermined time. However, for investigating shock velocities, it has been found convenient to get multiple exposures (Figs. 4a and 4b), which permits the measurement of distance as a function of time on each individual frame.

<div align="center">

### Components of the Ultra High-Speed Camera

</div>

The components of this camera, shown in Figs. 5–7, are described below.

*1. First Imaging Lens.* One of a number of high-quality large aperture photographic objectives which are available is used depending on the size of the charge and the magnification of image desired at the framing grid. All of these lenses are long focal lengths (12 to 40 in.) as required by the physical setup in the blast chamber (Fig. 2).

*2. Framing Grid.* The grids most easily obtained and reasonably priced are made on opaque coated optical glass $4 \times 4 \times \frac{1}{8}$ in. The
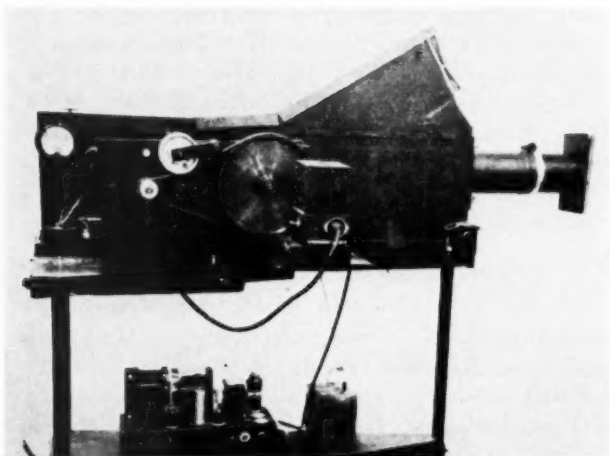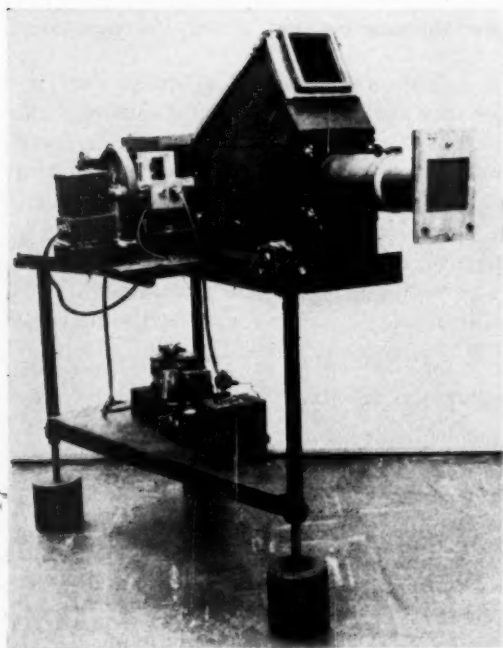
Fig. 5. Side view of camera.



Fig. 6. Three-quarter front view of camera showing grid in position.

.0005- and .0001-in. slits are cut with corresponding flat diamond points on a dividing engine.

*3. Second Imaging Lens.* This lens has a focal length of 360 mm. With the 1:1 magnification from the grid to the film plane the mirror can be placed to give an effective optical lever of about 20 in. Several photographic objectives with apertures of about $f/4.5$ have been tested. A high-quality process lens corrected for a flat field appears to resolve the slits most accurately.

*4. Rotating Mirror.* The 1-in. square face octagonal mirror in the Bowen rotating mirror camera is the aperture stop of the system. A 2-in. square flat mirror designed to rotate around its face will not



Fig. 7. Top view of camera showing optical system.

only take advantage of all of the light from the second lens but will eliminate the complicated form of the focal plane.

*5. Film Plane.* A standard $4 \times 5$ in. camera back is being used as illustrated.

*6. Synchronizing Circuit.* A hole in the wheel which drives the mirror passes a beam of light to a phototube which in turn fires a thyratron. This thyratron, operating at 400 v, then fires the charge directly or is used to trigger a timing circuit depending on the time requirements for the particular charge.

### Photographic Technique

Kodak Tri-X panchromatic plates have produced images of good density at exposure times of $10^{-8}$ sec. These plates are processed

in Kodak D19 developer for 20 min at 60 F. Base fog "latensification" of these plates has been used to obtain good image densities with developing times as short as 8 min at 65 F.

## REVIEWING THE FILM

Since the magnification from the grid to the film plane is 1:1, the negatives or contact printed positives can be viewed by placing the grid directly over them. Motion pictures can be observed by moving the photographic plate across the grid and frame-by-frame viewing is accomplished with a micrometer feed. Measurements are made at a magnification of 10 with a Bausch & Lomb contour projector. The sample reproductions in this report were made by enlarging through the grid properly positioned on a positive plate.

## CONCLUSIONS

The fundamental features of the design described in this report indicate limitless possibilities for obtaining ultra high-speed photographs of self-luminous phenomena. Probably, with the use of explosive-type flash bombs, or with Edgerton-type lights, nonluminous subjects can also be photographed at rates exceeding $10^8$ frames/sec.

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4. Fordyce E. Tuttle, "High-speed motion pictures by multiple-aperture focal-plane scanners," *Jour. SMPE*, vol. 53, pp. 451–461, Nov. 1949.
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# Flutter Measuring Set

By FRANK P. HERRNFELD

Ansco, Hollywood, Calif.

SUMMARY: The Flutter Measuring Set was built to measure the low percentage flutter of present-day recording and reproducing equipment. The set conforms to the "Proposed Standard Specifications for Flutter or Wow as Related to Sound Records," as outlined in the Society's *Journal* for August, 1947, pp. 147–159.

In keeping with the proposed specifications cited above, the instrument provides means for measuring percentage of flutter and drift. It will measure flutter at the nominal frequency of $3000 \pm 200$ cycles/sec. The input required for operation may be either $+8.0$ or $-52.0$ dbm. At these inputs, amplitude variations of $\pm 10$ db will not change the measurement by more than $2\%$. The percentage flutter meter is calibrated in percent for 0.1, 0.3 and $1.0\%$ full scale deflection. It indicates either true rms or average values by switching into the meter circuit either a thermocouple or selenium rectifier.

The percent drift meter is calibrated for 0.1, 0.3 and $1.0\%$ drift. The drift meter is also used as an indicator to tune the Flutter Measuring Set to the incoming signal frequency. The set is capable of reading rates of flutter from 0 to 200 cycles/sec. Networks are provided to read the following rate bands on the percent flutter meter: 2 to 200, 2 to 20, 20 to 200, and 96 cycles/sec. The drift meter is used to read 0 to 2 cycles/sec flutter rates. Outputs for a rapid recording oscillograph and an oscilloscope are provided.

## CIRCUIT

The flutter set consists of the following components:
(a) A pre-amplifier.
(b) A modulator-oscillator which converts the incoming 3000-cycle signal to 1000 cycles.
(c) A limiting amplifier.
(d) A frequency discriminating network which converts frequency-modulation into amplitude-modulation.
(e) An amplifier to increase the amplitude of the modulation signal.
(f) A selective network to break down the rate of the flutter into several bands.
(g) An indicating device.

The block diagram of the flutter set is shown in Fig. 1. With the input switch in the −52.0-db position, the flutter set is designed to work from a nominal 500- to 600-ohm impedance. The input is ungrounded. The wiring of the input plug is so arranged that the flutter measuring set can be grounded on one side, or it can be used in a balanced circuit by grounding the centertap of the input transformer.

The pre-amplifier consists of a nominal 500- to 60,000-ohm input transformer and two high-gain pentode tubes. The voltage gain from the 500-ohm input to the output of the second stage is adjusted to 60 db. Negative feedback is used to adjust the gain and to reduce the output impedance of the amplifier. No attempt has been made
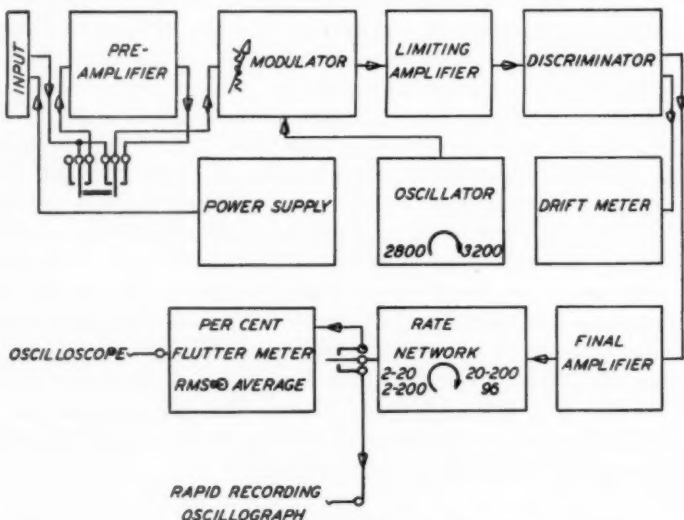


Fig. 1. Block diagram of flutter set.

to use the negative feedback for improving the frequency characteristic as the amplifier handles only a single frequency, namely, 3000 cycles/sec.

The input switch either connects the signal to the input transformer of the pre-amplifier giving the instrument a sensitivity of −60.0 db relative to 6 milliwatts or connects the input directly to the volume control preceding the modulator tube, giving the instrument a sensitivity of 0.0 db relative to 6 milliwatts. With the input switch in the 0.0-db position, one side of the circuit is grounded and the input looks like a true 4,000-ohm resistance.

In either position of the input switch an 85 volt polarizing voltage for a photoelectric cell appears on the input plug. This is done to

facilitate the use of the instrument, in the high-gain position, directly from a photoelectric cell.

The circuits for the modulator, oscillator and low-pass filter are shown in Fig. 2. The plate of the modulator tube is fed through the plate load resistance of the oscillator V2. The oscillator is of the electron-coupled type. Variations in the plate impedance of the modulator tube reflect very little into the oscillator section. The input to the modulator tube can be varied over $\pm 10$ db from its nominal "calibration" input without changing the frequency of the oscillator more than $\pm 1$ cycle at a mean frequency of 4,000 cycles.
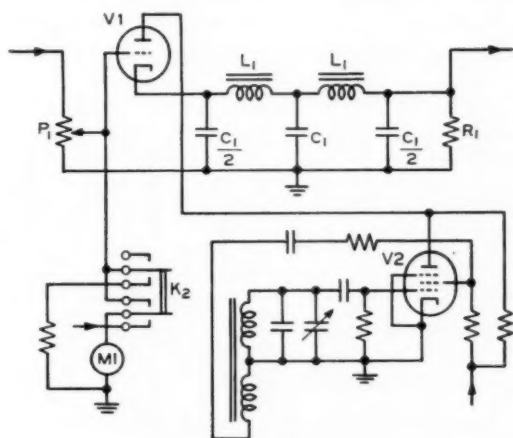


Figure 2.

This means that the instrument is capable of handling a signal with large amplitude changes without giving erroneous flutter readings.

The oscillator tunes from less than 3,800 to over 4,200 cycles. The discriminating network works at a frequency of 1,000 cycles; therefore, any input signal from 2,800 to 3,200 can be handled by the set.

The modulator tube is cathode loaded by $R_1$. $R_1$ is chosen of such value that it is equal to the output impedance of the modulator tube:

$$R_1 = \frac{R_p}{1 + \mu}$$

$R_1 =$ Load Resistance
$\mu \ =$ Amplification Factor of Tube
$R_p =$ Dynamic Plate Impedance of Tube

The image impedance of the low-pass filter following the modulator is equal to $R_1$, and its cutoff frequency lies at 1300 cycles. The low-

pass filter consists of two full constant-K sections, $L_1$ and $C_1$.  It will attenuate the signal and the oscillator tone by about 54 db, but will pass the beat, that is, the oscillator minus the signal frequency, unimpeded.

The output from the low-pass filter is fed directly into a three-stage limiting amplifier.

A duo-diode is located between the second and third tube of the limiting amplifier.  It is connected in such a manner that it will clip both the negative and positive peaks of the signal.

The clipping starts at about 16 db below the normal input level of the flutter set.  Clipping and the inherent insensitivity of the discriminating network to amplitude variation will make the output readings of the instrument virtually independent of variations in input
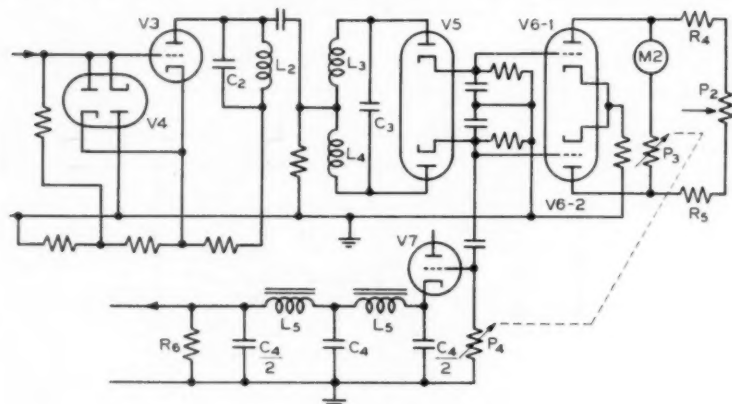


Figure 3.

voltage.  The last stage of the limiting amplifier feeds into the discriminating network directly.  Figure 3 shows the discriminator and allied circuits in detail.

The Q of the coils of the discriminating network and the coupling of $L_3$ and $L_4$ to $L_5$ must be such that the network will be able to pass a frequency band which is twice the maximum rate of flutter.  Therefore the band width over which the network must be linear is from 800 to 1200 cycles/sec.  For linearity it is important that the mutual coupling between $L_2$ and $L_3$ is the same as from $L_2$ to $L_4$.  For the same reason the product of $L_2 C_2$ must equal the product of $(L_3 + L_4) C_3$.

Careful adjustment of the discriminating network cannot be stressed too much, as the successful operation of the flutter measuring set depends on it.

The drift meter indicates rates between 0 and 2-cycles and is made up of V6, $R_4$, $R_5$, $P_2$, and M2. The meter is also used as a turing indicator to adjust the oscillator frequency to produce a 1000-cycle beat with the incoming signal. $P_2$ is used to adjust the plate currents of tube V6–1 and V6–2 to zero current through the meter M2 when no signal is applied.

V7 is a cathode-follower to couple the high impedance output of the discriminator to the low-pass filter $C_4$ $L_5$.

Again the load resistance $R_6$ is chosen of a value to make it equal to the output impedance of V7. The image impedance of the low-pass filter is the same as $R_6$ and the cut-off frequency is 250 cycles. The filter is a two-section constant-K type, and will attenuate the carrier frequency (1000 cycles/sec) by more than 50 db.
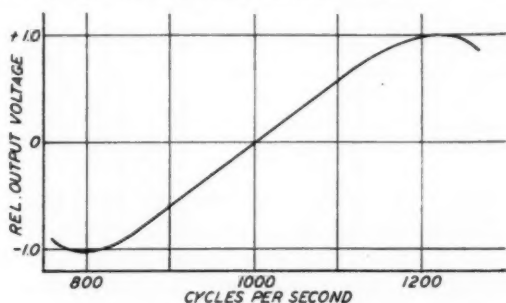


Figure 4.

$P_3$ and $P_4$ are two step potentiometers coupled by a common shaft, and are used to set the sensitivity of the flutter measuring set. They are set for 0.1, 0.3 and 1.0% flutter and drift measurements.

Figure 4 shows the response curve of the discriminating network when driven from a 10,000-ohm generator of constant amplitude. From this curve it is seen that the output is sufficiently linear with frequency to obviate the necessity for compensating circuits. When tested dynamically with a frequency-modulated audio-frequency oscillator (described by P. V. Smith and Ed Stanko in this JOURNAL in March, 1949) it was found that no nonlinearity existed.

The output from the low-pass filter is fed directly into the final amplifier. This amplifier has a frequency response uniform within 1 db from 1.5 to 200 cycles. Again negative feedback is used to adjust the gain and the output impedance of the amplifier. The plate voltage of the last tube is adjusted to such a value that the amplifier will work as a clipper at about 2 db above full-scale deflection of the meter. This is a very necessary precaution as transients frequently occur in

flutter measurements which may burn out the thermocouple of the meter.

The network following the final amplifier consists of a low-pass, high-pass and band-pass filter.   Figure 5 shows the frequency characteristics of the three filters when inserted between a 2600-ohm generator and a 2600-ohm load.

The percent flutter meter is connected directly across the output of the network switch.   The oscilloscope output is connected across the meter terminals.   Short-circuiting these terminals will also short-circuit the meter.   If the input impedance to the oscilloscope is normal (over 100,000 ohms), the meter readings will not be affected and both the meter and oscilloscope can be used simultaneously.
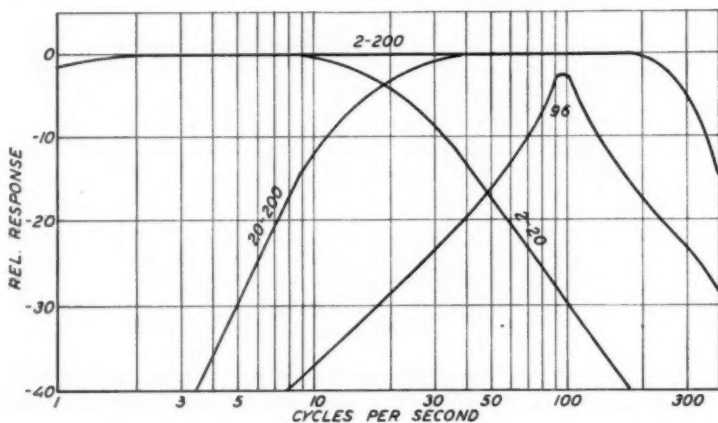


Figure 5.

The rapid recording oscillograph output is designed to work into a 500-ohm circuit.   If the oscillograph is plugged in, it will automatically lift the meter circuit.

### CONCLUSION

Two of the flutter measuring sets have been built and give satisfactory service.   The circuit is stable and independent of line voltage fluctuation.   Flutter readings of as low as 0.02% total, 2- to 200-cycle rate, are reproducible.

### ACKNOWLEDGMENT

# A Reflex 35-Mm Magazine
# Motion Picture Camera

By ANDRÉ COUTANT and JACQUES MATHOT

ETABLISSEMENTS CINÉMATOGRAPHIQUES ECLAIR, PARIS, FRANCE

TRANSLATED AND PRESENTED BY BENJAMIN BERG, HOLLYWOOD, CALIF.

SUMMARY: A new portable professional 35-mm motion picture camera has been recently introduced into this country from France, embodying the following characteristics: reflex shutter, adjustable from 200° to 40° (viewing is through the taking lens at all times); instantaneous loading of 400- or 100-ft magazines; divergent three-lens turret permitting use of 24- to 500-mm lenses without interference; interchangeable 6- or 8-volt electric motor, hand or spring drive; double pull-down ratchet movement with unique system of pressure pads and spring tensions to insure steadiness. The exterior shape of the camera is designed to fit the body, thus insuring steady hand held operation. The flat base of the camera is made to fit the rapid mounting dovetail of the tripod head.

WE HAVE TOGETHER designed the Camerette (Patents Coutant-Mathot) which last year was introduced in the United States. The Camerette is manufactured in Paris, France, by the Etablissements Cinématographiques Eclair, manufacturers of the Cameréclair 400-Ft and of the Cameréclair Studio 1000-Ft cameras. The Camerette's name for the European market is "Caméflex."

In 1944, during the German occupation, we decided to put our ideas together to create a really modern portable camera. Drawing upon the twenty years of experience we had in the motion picture industry, we each had specific ideas about the conditions a portable camera would have to meet to answer the needs of the cameraman and the producer.

Our basic ideas have been patented, called "Patents Coutant-Mathot," and these patents cover the main Camerette features, most of which are completely new. We will be happy if we have succeeded in making the work of the cameraman easier, and if we have helped to improve motion picture camera techniques.

The principal characteristics of the camera are as follows:

*General Shape.* The shape of the camera with the 400-ft magazine attached is such that it can easily be hand held by resting the magazine on the shoulder, holding the camera by the motor with the right
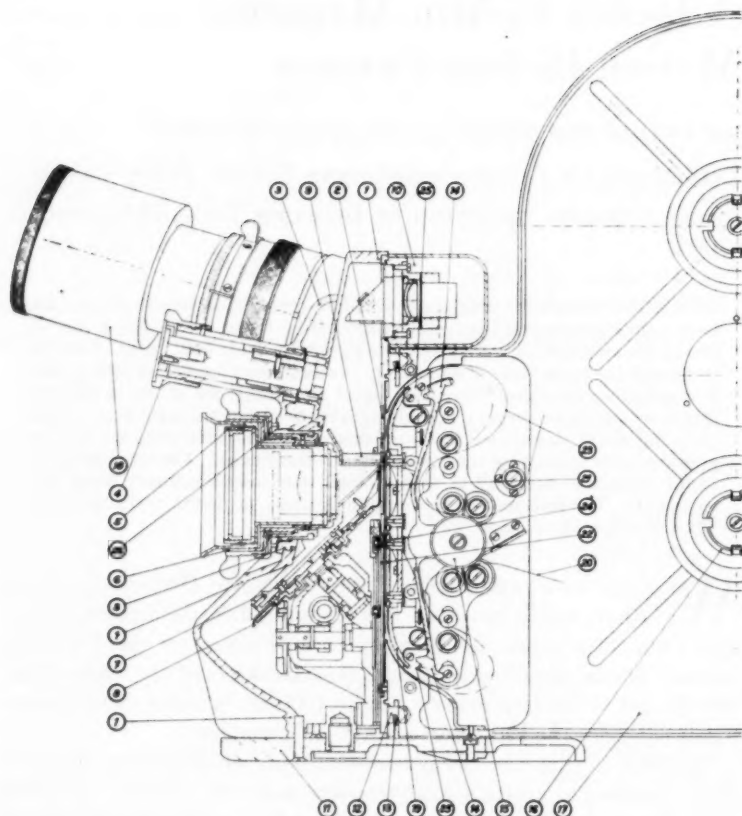
Fig. 1. Diagram of the Camerette.

1. Front section
2. Front aperture plate
3. Base or seat of the turret
4. Turret lock
5. Standard filter holder for lens
6. Lens mounting
7. Silvered mirror placed on the front of the shutter blade
8. Shutter and its mounting
9. Ground glass
10. Prisms
11. Flat camera base, fitting the special dovetail in rapid mounting tripod head
12. Magazine engaging bolt
13. Groove for magazine lock
14. Light traps which are automatically opened when magazine is attached to camera

15. Sprocket
16. Take-up hub with spring clips accepting standard film spools, male or female
17. 400-ft automatic film gate magazine
18. Lens shade shown on 100-mm lens
19. Rear channel of film on magazine
20. Film passage to take-up spool
21. Top pressure pad maintaining film No. 23 in proper position at the aperture No. 2
22. Bottom pressure pad keeping the film properly aligned for the pull-down claws No. 24
23. Film, upper loop
24. Pull-down claws
25. Tempered steel pad for the lateral spring guides

hand, using the left hand to focus the lens, and support the camera. The balance and shape are such as to give extremely steady hand-held operation since the camera is held close to the body, and firmly supported. The flat base of the camera (Fig. 1-*11*) and the eyepiece swinging into the vertical viewing position allow for placing the camera on the ground without the use of any support. Use on the tripod is equally rapidly accomplished by means of the rapid mounting dovetail head.

*Viewing* is through the taking lens by reflection from an unbreakable front silvered mirror placed on the front of the shutter blade, and rotating with it (Fig. 1-*7*). This image is transmitted by a ground glass (Fig. 1-*9*) and prisms (Fig. 1-*10*) to the magnifying eyepiece. The eyepiece is fitted with a calibrated focusing adjustment, and can be set in three positions: horizontal for normal use, vertical when the camera is used from a very low angle, and, when not in use, the eyepiece is placed in the lowered position for storage in the carrying case. A self-closing light guard is provided for use in direct sunlight or other strong light; under normal lighting conditions its use is not required. The camera can be obtained with either right or left eyepieces. This reflex method of viewing eliminates the necessity of auxiliary finders, has the advantage of accurate framing with no parallax, and makes it possible to follow focus visually during actual filming.

*Magazines.* The automatic film gate magazines are available in either 400- or 100-ft film capacities, and can be used interchangeably. Magazines are instantly attached and locked to the camera unit by a simple pressure of the hand. Unlocking is equally rapid by pressing the locking knob and removing the magazine. Magazines can be changed while the camera is in operation. The camera has its best balance for hand-held operation with the 400-ft magazine, since the magazine can be supported on the operator's shoulder, permitting steadier work with less fatigue, because of the excellent weight distribution.

There are two fiber pressure pads on the front of the magazine, the upper pad maintaining the film in the proper position at the aperture, the lower one insuring steadiness, guiding the film in its relation to the pull-down claws, situated on the camera proper. The double pull-down claws, pressure pads and guides which keep the film traveling in a straight path past the aperture insure absolute steadiness.

The preloaded automatic magazines offer a distinct advantage in the saving of production time due to waits for reloading. For cold weather operations where loading becomes a problem because of the
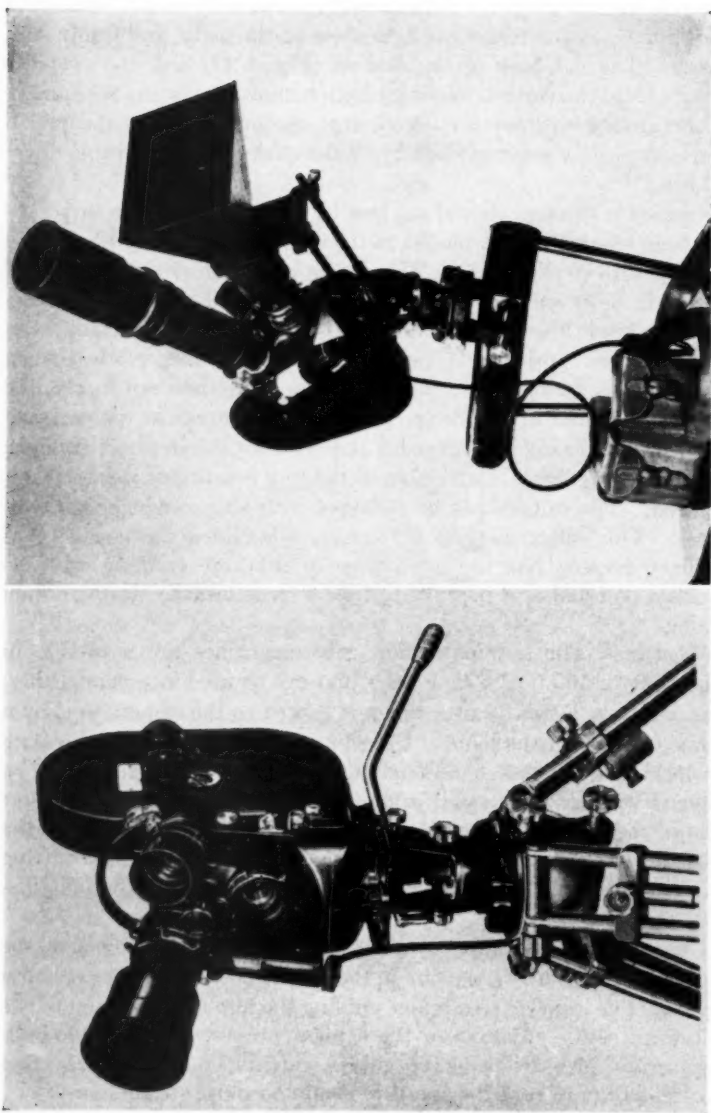
Fig. 3. Camerette with auxiliary clamp and battery pack.

Fig. 2. Camerette.

necessity of wearing thick fur gloves, the preloaded automatic film gate magazine is the obvious solution. Loading the magazines is simple, and can be done in either darkroom or changing bag. The loops are formed in daylight, and are not critical. Film wound either emulsion in or out can be used.

Figure 4 shows the method of attaching the magazines to the camera.



Fig. 4. Attaching the film magazine.

*Movement and Aperture Plate.* The movement consists of two ratchet pull-down claws engaging the film, which is kept in its proper position by the two pressure pads on the film gate magazine. The top pad is designed to keep the film flat and in the focal plane. The surface of the pressure pad and the system of pressure applied are such as to avoid all pressure against a hard surface, thus preventing distortion of the film at the aperture. The bottom pad, which holds the film only at the edges, keeps the film properly aligned for the pull-down claws, insuring absolute steadiness. The lateral guidance is assured by two spring guides in the magazine, placed in the curved parts of

the film loops. By keeping this pressure in the loops, warping or twisting of the film is prevented, since there is more resistance to lateral pressure in the curved sections. The elimination of aperture pins permits simpler, more compact construction, with consequent freedom from mechanical failure and repairs. Another advantage of this type of movement is the camera's adaptability to extreme changes of temperature, since wide variations in film and perforation size can be tolerated.

The aperture plate is made of one piece of stainless steel, hand polished and undercut to prevent scratching. With the magazine removed, the plate is readily accessible for checking and cleaning. A special guard is provided for the aperture plate to prevent damage when the camera is dismounted for packing.

*Shutter.* The shutter blade, in front of which is placed the reflex mirror, has a maximum aperture of 200°. This is adjustable to 40° by means of a graduated shutter disc (sliding behind the reflecting mirror); its position is controlled by an exterior knob. The Camerette Model C has a 230° shutter, adjustable to 110°. See Fig. 1–*8*.

*Drive.* There are three alternative drives for the camera: electric motor, spring motor or hand-gear box. The change from one to the other can be rapidly and easily accomplished. The electric motors and hand-gear boxes are placed on the side of the camera at the right hand of the operator. The spring motor attaches to a special support on the back of the camera and rests beside the magazine. The standard electric motor serves as the handle for the camera.

The starting and stopping switches are in front and are operated by the little finger of the right hand. Speed control is obtained by turning the rheostat knob on the top of the motor with the thumb of the right hand, while holding the release catch with the index finger. This motor operates on either 6 or 8 volts of direct current supplied by a set of lead batteries. The batteries are mounted in a leather waist belt for carrying, and weigh 9 lb. An electric charger operating on either 110 or 220 volts is part of the standard equipment. The batteries have a capacity of 15 amp-hr and will operate ten 400-ft magazines, or 4000 ft of film, on one charge. The motor switch has three positions, the middle position cutting out the rheostat for a fraction of a second to help overcome starting inertia, enabling the camera to come to speed quickly. This position can be utilized also to change the camera from high to normal speeds without changing the setting of the rheostat.

The spring motor, used only in emergency, is entirely ball bearing mounted, and will resist extremely cold temperatures. It is capable of running 45 ft of film on each wind. There is a button for speed regulation, and a crank for winding.

The hand-gear box attaches in the same position as the electric motor. There are three gear ratios, one, eight, or sixteen frames per revolution of the crank. A 220-volt, 50-cycle synchronous motor is also available.

*Turret.* The divergent three-lens turret is designed to accommodate lenses from 24 to 500 mm without cut-off. The standard mounts are of the bayonet type, fitted with grips for focusing, and lens hoods with spring clips in which either the metal lens caps or filter holders can be inserted. Mounts are available for any standard lenses. Normally the camera is supplied with Kinoptik lenses which are coated F2 apochromats available in focal lengths from 25 to 500 mm. (See Figs. 1–5 and 1–6.)

*Filters.* Three types of filter mounts are supplied.

1. Round filters which clip inside the sunshade of each lens (diameter of filters 40 to 75 mm).

2. Gelatin filter holders placed behind the lens in the aperture.

3. Regular Wratten 3-in. square filters can be used in the matte box, which will accommodate two such filters. (Fig. 1–5 shows round-type filter holder incorporated in lens house.)

*Tachometer.* The camera is provided with a magnetic tachometer, graduated from 8 to 40 frames/sec.

*Tripod and Tripod Head.* The special tripod supplied with the camera is made of dural, and weighs only 13 lb with the normal legs. It measures, closed, 3 ft 5 in., and 5 ft 6 in. fully extended. Medium and baby legs are available and can be easily attached to the tripod head. The tripod head can be rapidly detached from the legs by means of a clamp. An auxiliary clamp is also provided, permitting fastening the camera on any type of support. The camera is mounted on the tripod by means of a dovetail which receives the flat base of the camera, and locked into place by a spring bolt. Pulling down on the spring bolt and starting the camera out of the dovetail by means of the cam lever on the tripod head frees the camera from the tripod. A pan handle is carried on a clip on the tripod.

The exterior of the camera is protected by a black anodized finish, which is very durable, weather and shock resistant. The camera, with motor, three lenses and 400-ft magazine, weighs only 14 lb.

# Economy in Small-Scale Motion Picture Lighting

By ARTHUR L. SMITH

211 CORNELL ST., ITHACA, N.Y.

SUMMARY: There is an apparent need and trend toward reducing the amount of electric power required for illumination in motion picture production. Although the interest in this situation extends through the entire industry, the greatest economic significance probably concerns the smaller nontheatrical producers, many of whom are working with direct 16-mm film. For present purposes, this report considers only the problem of small sets and field work.

IN A GENERAL CONSIDERATION of the lighting equipment required by small producers, several factors are immediately evident: (1) dependent on the location and size of the set or scene, the lighting required may vary considerably in both type and volume; (2) the quantity of lighting units available among small producers varies to great extremes; (3) the economy of operation is an almost universal problem; (4) the art of scene lighting is affected by the lighting units available; and (5) there are many electrical factors which must be given due consideration.

Specifically, such problems arise as how to accomplish filming with minimum power, how to decrease the expense of new power installations, how to provide an increased over-all lighting for the slower color films without greater amperage, how to acquire quantity lighting without adding many expensive lighting units, and how best to distribute the available electric power service from the viewpoint of economy. These questions are common to many small producers. Before attempting suggestions which may provide answers to some of these and other problems, it seems important to consider lighting in general.

During the rapid development of the theatrical film industry, standard lighting equipment evolved which in its entirety provides dozens of types, styles and wattages of illuminants. Two principal classifications, arc lamps and incandescent lamps, can be subdivided into a host of forms among the variously sized flood lamps, spot lamps and intermediates. This complexity of lighting equipment is justifiable within the major film studios. It is not possible, however,

for the small 16-mm producer to emulate such conditions, nor is that necessarily desirable. It is then a question of selecting the least number of lighting units which can provide adequate illumination for the scope of production involved. In simplifying the range of lamps, a primary consideration is that of achieving the possibility of well-balanced and well-modeled scene lighting. In the same sense that the creation of good lighting is an art, so are the lights the tools of the trade. In most instances it is critical that (1) a means be provided for creating a general level of all-over lighting, (2) that individual lights be available for specific modeling and accents, and (3) that a means is provided for creating high levels of directional penetrating light to create sunlight effects, produce specific shadows, and so forth.

Figure 1 contains a group of sketches illustrating a number of important basic types of lights. A present conclusion is that almost any producer will require certain of these units and particularly a number of adjustable spotlights and versatile flood units for modeling purposes.

There are many combinations of lighting equipment encountered among small producers. Filming has been done with a few simple reflectors on collapsible stands. More commonly, a small studio will have an assortment of fresnel lens keg spotlights, a number of open floods in various reflectors, and one or more high-wattage arc or incandescent spot units. Unless numerous standard floods are grouped to provide a basic level of illumination, the greatest problem usually appears as the need for a form of over-all gross lighting which is diffuse, of high intensity, of the lowest possible amperage and the least in expense.

One such system which seems to be acquiring popularity is low-amperage Colortran.[1] Another method, as devised by the author, employs banks of reflectorfloods in much the same manner as used in certain parts of television lighting.[2]

### BANKS OF REFLECTORFLOODS

It is well known that the "photoflood" type of lamp, when burned at 110 to 120 v, will produce far more effective wattage per ampere than conventional incandescent lamps. The issuance of the reflectorflood lamps, which provide a built-in directional distribution of all their light, has proved to be of considerable value in the problem of concentrating large amounts of illumination in restricted areas. With a built-in reflector, the need for a larger controlling reflector is eliminated and an important gain is made in both space and expense.
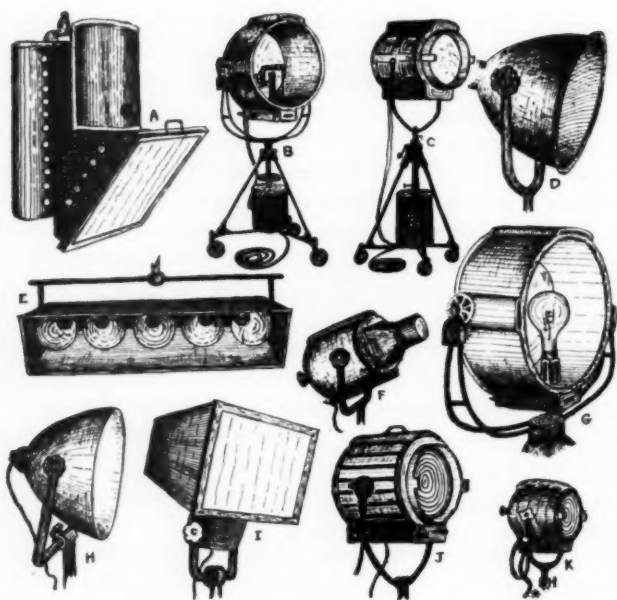
Fig. 1. Rough sketches of some basic types of lights: A, scoop; B, sun arc; C, arc spotlamp; D, rifle lamp; E, strip light; F, small spot with focusing snout; G, incandescent sunspot; H, open bowl flood; I, broadside; J, senior solarspot; and K, baby keg.



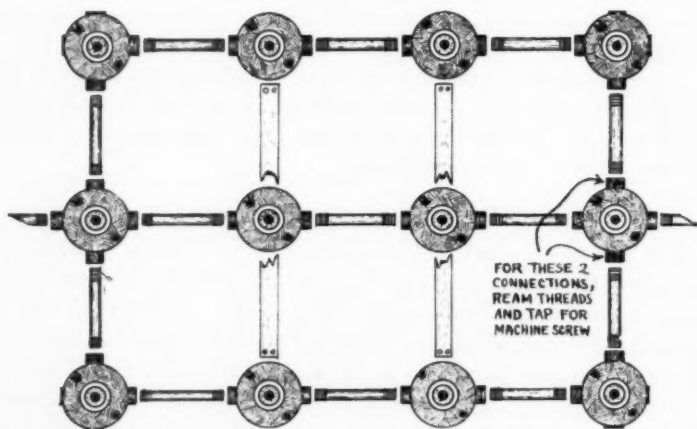FOR THESE 2 CONNECTIONS, REAM THREADS AND TAP FOR MACHINE SCREW

Fig. 2. "Exploded" view of lamp bank layout.

By grouping twelve such reflectorfloods into a bank, a highly potent source of light providing the equivalent of 18,000 w may be secured from an area of about 2 × 3 ft. Each such bank draws only 60 amp as contrasted to approximately 180 amp of normal lighting. The weight of cable required is drastically reduced both from the power source and to the individual lamps. Another added advantage is the simple and inexpensive means of constructing the lamp bank.

In the case of most good quality standard lighting equipment, there is no cheap substitute. With reflectorflood banks, however, it is very easy to provide an inexpensive assembly which lacks nothing in
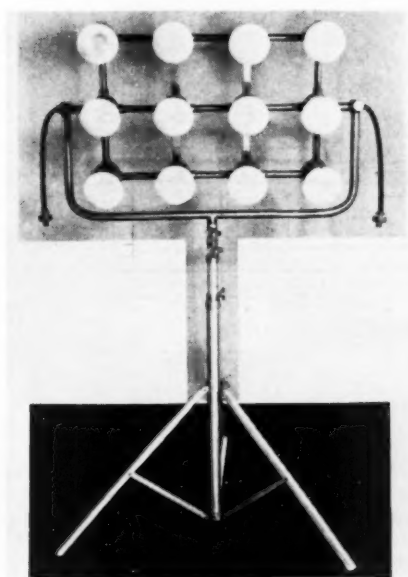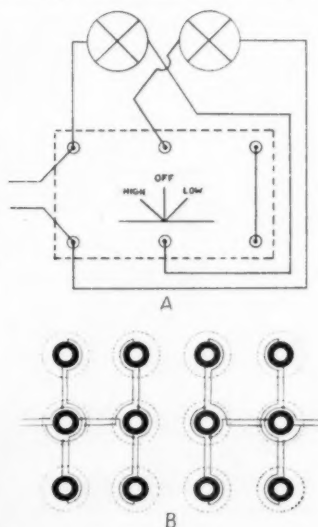


Fig. 3. Complete lamp on Saltzman stand.

Fig. 4. A, simple series-parallel circuit with double-pole–double-throw, center-off switch; B, six lamps in parallel against six others.

utility. Lightweight cast aluminum condulets with appropriately placed and threaded connection points (Fig. 2) can be spaced by long 7- or 8-in. end-threaded nipples. To accommodate final assembly, strap bars can be added to the two central vertical rows. A framing yoke of conduit tubing can allow for angular positioning. The central yoke attachment to a stand can be constructed to permit rotation of the entire bank. This method of assembly provides all the necessary movement and setscrews may be used to retain locked positions. The stand itself may be of any desired type. In the

present instance, mobility was critical and the very light and rugged Saltzman collapsible magnesium stands were secured (Fig. 3). These stands have a remarkably long maximum extension and a firm base.

Thus for a total material cost of about $60, which includes stands, lamp banks of 18,000 w can be secured. Five such banks used for diffuse fill-type of illumination can provide 90,000 w for only 300 amp. If this same area were lighted by the use of individual or strip 2,000-lamps, 45 bulbs drawing about 800 amp and occupying considerable space would be required.
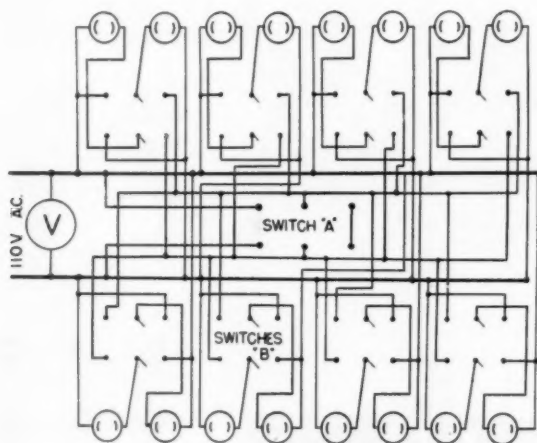


Fig. 5. Plan for a master plugging box based on series-parallel circuit and employing master switch. Switch "A" is Westinghouse Class 11-210-MS2 relay type operated by remote high-low-off push-button station. Switches "B" are Westinghouse reversing drum type N-103-E. Switch "A" may also be obtained for 220 v where input current is three-wire 220–110-v.

## Dimming Devices

One of the principal objections to the use of the photoflood-type light is its relatively short life. The expense as well as the nuisance of constant replacement has limited its use in professional filming. The answer to these problems is found in the use of dimming units whereby the lamps may be burned at reduced brightness during preparation and between takes. Since adjustable rheostats and transformers would be heavy and costly, the simple method of high-low switching by a series-parallel circuit appears as the most economical system.
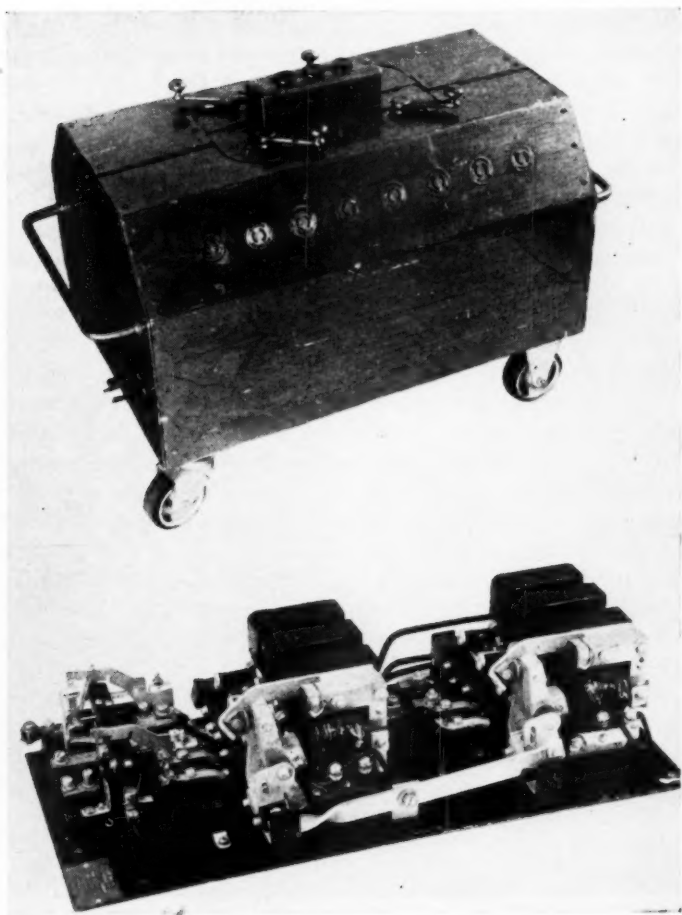
Fig. 6. Above, portable 300-amp capacity plugging box;
below, master relay switch.

In the use of a series-parallel circuit, a double-pole–double-throw, center-off switch may be employed as in Fig. 4a.   Since it would be impractical to use a switch for each pair of reflectorflood lamps, a bank of twelve lamps may be divided so that six are balanced against six while in series (Fig. 4b).   To eliminate the confusion of multiple switching points, each pair of cables may be brought to a centrally located portable switching box.   It is difficult to secure snap switches

of the double-pole–double-throw type which will carry a total load
of 60 amp and the use of knife switches is not convenient. A drum
·switch, such as the Westinghouse Type N-103-E, can be easily
modified to serve, is quite inexpensive, extremely rugged and of ade-
quate rating.

The use of series-parallel switching may also be applied to other
units employed on the set. Their cables also may be brought to a
central plugging box and all the lighting controlled from a single area.

Where labor, time and efficiency are critical, a further refinement
may be added. By using a special master relay switch operated by
remote control, it is possible to have all of the lighting units in use
controlled by a single high-low-off push-button station. Although
the use of simple series-parallel circuits is quite common, the addi-
tion of a master switch seems to have been largely ignored in motion
picture lighting. Several years ago, the author devised a circuit of
this type[3] which has since been revised to permit amperages up to
300 amp per master switch (Fig. 5). If more than 300 amp are re-
quired, extra master switches may be added and controlled by the
same push-button station as the original.

In professional use, the plugging box and master switch (Fig. 6)
are found to have notable advantages for saving time. Where small
crews are employed, the entire set lighting may be culminated in a
single box and switched to bright, dim or off with the touch of the
cameraman's or director's finger. The cost of the switches for a
master control plugging box accommodating sixteen lamps (for
example, three twelve-lamp banks and ten other units) by remote
control would be less than two hundred dollars. If the drum switches
for individual pairs are eliminated, the cost will be much less than one
hundred dollars.

### ELECTRICAL CONSIDERATIONS

A problem which is related in economy and efficiency to lighting,
concerns the electrical materials and factors involved in providing
power. Although the time-honored Kleigl and other types of stand-
ard connectors and branch-offs seem still to be in predominant use,
there seems also to be some justification for considering other devices.
Any production set electrician who has used nonlockable plugs has
doubtlessly experienced unplanned disconnections. Inexpensive
Twistlock connectors will carry up to 20 amp and easily overload to
30 amp. Their use is so simple and their positive locking action so
durable that it is surprising not to encounter them more often. When
loads of greater power are to be carried, Hubbelock connectors may

be employed. Some of the four-contact type with pairs barred to-
gether are rated at 70 amp and have carried over 150 amp without
trouble for the author. These connectors are available in styles
which are watertight and for certain field work this advantage is
critical. Four-prong Cannon-type plugs rated at 200 amp have
been adapted satisfactorily.

Many producers decrease cable size and cost by bringing main
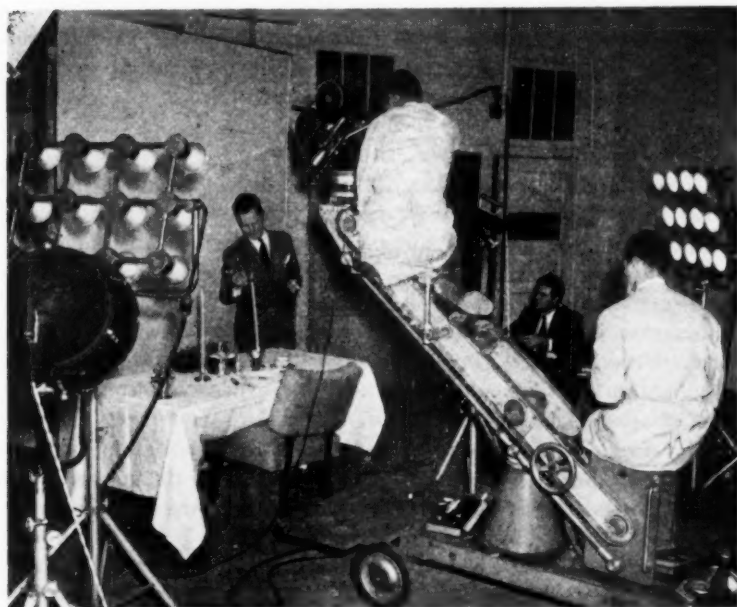power lines to a distribution point on a three-wire 220–110-v circuit.



Fig. 7. Lamp banks assembled and ready for use in small studio scene.

This device may also be used in connection with a remote control
plugging box, half of the current going to each side of the box. In
this instance, the weight of the cable will, of course, bear a relation
to the capacity of the box and although an open temporary cable
may be somewhat overloaded, an extreme in this regard may be
dangerous as well as decrease the input voltage and cause a lowering
in the intensity and color of the lamps. Fortunately voltage drops
in main line cables are not as great with 220 v as with direct 110 v and
this is an added advantage of the three-wire 220–110-v system.

If power is to be supplied through direct lines without series-parallel switching, a very durable, safe and inexpensive service can be obtained with the use of a breaker panel. For example, a panel having twelve 50-amp breakers can be used with twelve Hubbelock receptacles mounted in the gutters. By a curious coincidence an entire panel may be secured with optional breaker capacities up to 50 amp each without adding to the basic price of about sixty-five dollars. The main bus bars can also be specified of a weight to permit distribution of a total load of around 400 amp.

Many of the various electrical connectors and power boxes required for heavy amperage are extremely expensive. It is for this reason that it seems important to note those particular materials which are rugged, suitable and least expensive.

## CONCLUSIONS

An attempt has been made to outline various means by which a small producer may secure a reasonably professional quantity and quality of motion picture illumination on a basis of added efficiency and economy. Standard types of lighting have been retained for modeling, accent, high key and character. The basic level of illumination is obtained by reflectorflood banks which in turn are made efficient by means of a master switching box. This system of illumination provides added wattage by inexpensive means and the critical art of lighting employs essentially the same "tools" as those of the standard large scale studio. Heat from set lighting may be reduced by dim settings of either pair of switches or the master switch except for the time of actual shooting, thus providing comfort for the cast and extending lamp life by five or ten times.

A great many of the new and smaller production services are faced with the high acquisition cost of good-quality lighting units on today's market. Rather than sacrifice picture quality or operate largely with open lens apertures, it seems desirable to utilize a type of lighting which possesses both economic and professional advantages.

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# Component Arrangement for a Versatile Television Receiver

By F. N. GILLETTE

GENERAL PRECISION LABORATORY, INC., PLEASANTVILLE, N.Y.

AND J. S. EWING

THE HERTNER ELECTRIC CO., CLEVELAND 11, OHIO

SUMMARY: The requirements and the arrangement of the various elements of a rather versatile television receiving system are described. A commercial unit is used to illustrate some of the practical applications of ideas suggested in this paper.

COINCIDENT WITH large scale utilization of home television receivers, there has been an increasing demand for a television receiving system of a somewhat more elaborate nature, for a larger and more critical audience.

The demand of such a system can well be understood when one stops to consider the potentialities of television programs, not only for entertainment purposes, but also for educational and industrial uses. Several examples of possible applications of such a system can best be represented by the present-day use of both the Army and Navy of television for training and experimental programs. Philadelphia and other school systems are using television programs as an additional aid in their educational systems, and recently the medical profession has applied television for viewing surgical operations.

The utilization of such a system will be, in general, by an audience larger than can be accommodated by a single home-type receiver, and thus it is inferred that a projection type unit will be employed. The purpose of this paper is to discuss the arrangement and considerations given to the elements of such a system and later on to describe a unit employing some of these basic concepts.

Figure 1 shows a block diagram of a possible receiving system. This diagram describes a somewhat elaborate installation, showing a few of the possible combinations that can be achieved with this arrangement. However, by proper choice of basic elements this system can be reduced in magnitude and still provide suitable service, dependent on the size and requirement of the installation.

It should be noted from Fig. 1 that the system is broken down into groups of individual chassis, each performing a basic function of a tele-

vision receiving system.    Certain ones of the chassis can be removed, modified, or added to the system in order to meet the requirements of the individual installation.    Each of the principal chassis could obtain its own power supply so that its removal or addition would not affect the operation of the over-all system.    This arrangement also simplifies testing and servicing.

The antenna lead-in cable is shown connected to the control box as the r-f (radio-frequency) tuner is situated in this unit.    Locating the r-f tuner in this manner makes it possible to provide remote station selection without resorting to an elaborate servo or step-type mechanism.    This feature is accomplished by connecting the out-
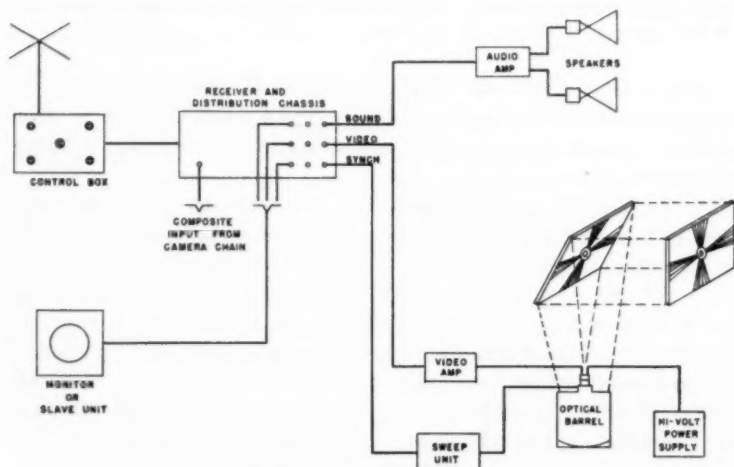


Fig. 1. A receiving system.

put of the mixer stage to the first i-f (intermediate-frequency) stage by means of a low-impedance link, coupled through shielded coaxial cable.    If the unit is to be operated on other than the standard channels, it is only necessary to exchange the r-f tuner for one matching the desired frequencies, the only proviso being that the intermediate frequency of the system remain the same.

The r-f tuner should be of such design that a booster amplifier should not normally be required.    Maximum useful sensitivity consistent with a good signal-to-noise ratio and unwanted signal rejection, without a sacrifice to bandwidth, are the prime requisites of the r-f tuner.

The remaining controls (also located in the control box), such as

contrast, brightness, tone, volume and the master power switch, should operate on d-c voltages wherever possible in order to reduce the amount of cable required at installation and also to eliminate the necessity of returning signal voltage to the control box, to avoid possible signal distortion.

The composite sound, synchronization and video signal is naturally brought into the receiver and distribution chassis at intermediate frequency. The i-f stages of the receiver follow the usual design pattern, with special precautions taken to insure proper bandwidth, sufficient gain and ample trapping for adjacent channel interference.

Based on past experiences, and with minor circuit changes, a convenient input jack should be provided, to permit the input from a closed loop camera chain to be easily switched into the circuit after the second detector.

In the system of this nature it is desirable to employ a well designed a-g-c (automatic-gain-control) circuit which would be located in the receiver and distribution chassis. Automatic gain control, besides reducing the effects of varying input signal levels, also helps to suppress random interference from noise signals. It is also of value in insuring that synchronization signals actuating the sweep circuits operate from the same relative level with each operating pulse. This type of operation serves to remove a certain amount of jitter in the picture, which would otherwise be noticeable.

In order to provide for maximum flexibility in the choice and location of the sound and projection system, the sound, synchronization and video signals, after proper separation and detection, are applied to individual low-impedance line-driven amplifiers. Several of these low-impedance amplifiers can be operated in parallel so as to provide additional outlets to monitor or "slave" units.

The size and method of producing the projected picture determine the ultimate design of the sweep chassis; however, certain fundamental features should be incorporated in its specifications. Maximum consideration should be given to the design of the sweep generation circuits to insure linearity of sweep, stable synchronization and elimination of pairing, because minor irregularities, not noticeable on small-size screens, are quite evident when the picture is enlarged.

To meet these requirements, it is advisable to utilize automatic synchronizing circuits in both the vertical and horizontal sweep generators. In order to retain flexibility and also to remove a possible source of interference to synchronization, the high-voltage power supply should be divorced from the sweep chassis.

The high-voltage power supply will depend on the type of projec-

tion system employed. It should be well regulated with respect to variations in line voltage and average picture brightness. In order to reduce the danger of shock hazard to operating personnel and also to reduce the size of the unit, it is desirable to operate the high-voltage power supply at a frequency higher than line frequency. The energy storage capacity of the filter units required at power-line frequencies makes these units quite lethal. If an r-f type of high voltage power supply is employed, adequate shielding should be provided in order to prevent interfering signals being picked up by the receiver chassis.

The video amplifier is placed in a separate chassis so that its size and location can be chosen to meet the type of projection unit employed. If a separate amplifier were not used, the distance between the projection equipment and the receiving equipment could be the limiting factor on the high-frequency response due to the shunt capacitance of the projection tube.

In order that the high fidelity transmission of the f-m (frequency-modulation) sound signal be used to advantage, the audio system should be of high quality to be capable of reproducing the audio-modulation range of 50 to 15,000 cycles/sec, which is used in the f-m transmission for television sound. Again, the power handling capability and location of the unit will be dependent on the type of installation.

The viewing system is dependent on the picture-size requirement of the installation. Two methods are currently being used; one is by direct view from the cathode-ray tube, the other by projection from the face of the cathode-ray tube; however, other methods are possible, such as film recording and projection.

The direct-view method is somewhat limited as to the number of people that can be accommodated by it. However, in some cases, this drawback can be circumvented by using a number of direct-view "slave" units. The technique used would be the same as that employed in home television receivers.

Figure 1 indicates a rear-view projection system. However, it is possible to use front projection with the optical barrel suspended from the ceiling, or mounted on a fixed or movable dolly. Projection from the face of the cathode-ray tube affords an excellent method for increasing the screen size; however, certain technical limitations place a limit on the size and brightness of the picture that can be obtained with this method. In order to obtain maximum results with this method, a highly efficient optical system must be employed. At present the Schmidt system, or variations of it, give the best results. Corrections should be made for distortion and aberration.

### THE PRECISION TELEVISION RECEIVER

The Precision Television Receiver demonstrates some of the practical aspects of this paper. Although built as a packaged unit to simplify installation, it nevertheless incorporates some of the features
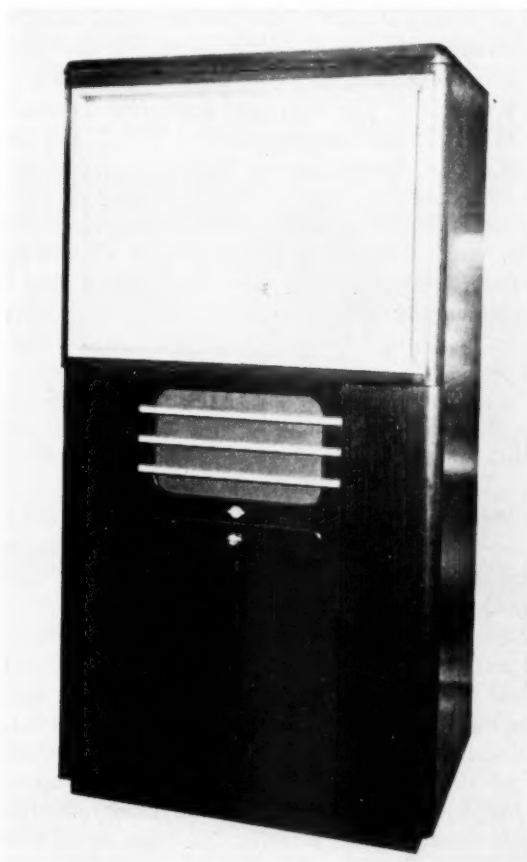


Fig. 2. The Precision Television Receiver.

discussed in this paper. Figure 2 shows the front view of the unit, and Fig. 3 shows the arrangement and interconnections of the various chassis used in this receiver. With minor changes, the components of this system can be extended to include the elaborate arrangement earlier described.

The precision Television Receiver Model L–10 features a 27 × 36 in. rear-projected picture. In order to obtain a picture of this size, a 5TP4 projection tube with 30 kv applied to the second anode is used in conjunction with a Schmidt optical system. The optical system consists of an optical barrel supporting the projection tube, the 12-in. front-surfaced spherical mirror and the corrector lens. A 45-deg, front-surfaced mirror located in the top section of the cabinet directs the reflected light onto the rear of a plastic translucent screen having directional properties. The high-light brightness as measured on a standard test pattern has been measured at 30 ft-L and the resolving power of the optical system has also been measured to be somewhat better than 1000 lines.

The r-f tuner is shown mounted on the receiver chassis but it can be conveniently removed to serve a remote location without changing its operating characteristics, because the output transformer used is designed so as to connect with the first i-f amplifier stage through a low-impedance link coupling. The cable used to effect the coupling can be any commercial, 90-ohm, shielded coaxial cable up to 50 ft in length.

Channel selection is made by switching to individually tuned circuits for each section of the tuner circuit. These tuned circuits are mounted on low-loss bakelite clips which snap into their individual sections on a turret selector. The sequence of selection can be easily arranged in any desired fashion. If desired, tuned circuits for operating on channels other than standard can easily be inserted. This tuner is capable of 100-$\mu$v sensitivity at normal bandwidth with an average signal-to-noise ratio of eleven to one.

The first two stages of i-f amplification are common to both the sound and picture signals. The sound signal is separated from the picture signal in the plate circuit of the second stage and after additional amplification and limiting, the signal is then detected in a frequency discriminator stage. The picture signal passes through two additional i-f stages before being detected. Six trap circuits are utilized in the picture stages to remove the undesired adjacent channel and sound signals. After detection the video signal is applied to a cathode follower stage designed to match a coaxial cable feeding the remote video amplifier.

A separate detection stage is utilized to separate a portion of the video signal for operating the automatic gain control and synchronization separation circuits. The synchronization signal is further amplified before being applied to a cathode follower stage for line matching to the sweep chassis. The signal for automatic gain control is d-c amplified and filtered in three stages and is designed so as to give

separate delay characteristics to the r-f and the i-f stages controlled by automatic gain control. The amplified a-g-c circuit in this receiver will equalize the second detector output for a range of signals between 500 $\mu$v minimum and 40 mv maximum.

The sound amplifier of this system is also shown mounted on the same chassis as the receiver; however, this unit can easily be divorced from the receiver chassis for remote-location purposes. The amplifier is capable of 20-w power output and when the bass and treble controls are cut out of the circuit, the response is essentially flat to 20,000 cycles. At 20-w output the harmonic content at center frequency
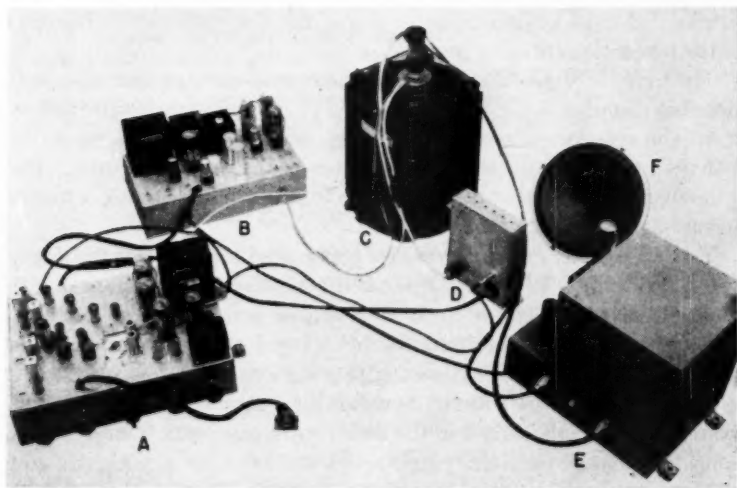


Fig. 3. Arrangement and interconnections of various chassis.

A, receiver and sound chassis    C, optical barrel    E, 30-kv high-voltage supply
B, sweep chassis             D, video amplifier   F, speaker

has been measured to be $1\frac{1}{2}\%$. For the same power output, the harmonic content for both the lower and upper part of the frequency spectrum has been measured at 2.2%. A 12-in. permanent magnet speaker, with a power rating of 25 w, is used to load the sound amplifier.

The sweep unit is shown as an additional chassis and contains its own power supply. It is only necessary to change the deflection output transformers of this unit in order to operate projection tubes having a higher second anode voltage than the 30 kv rated as maximum for the 5TP4 tube. The horizontal and vertical sweep oscillators are

so well stabilized that under the worst condition of noise, where a picture is just barely visible through the snow, no trouble is encountered in maintaining synchronization.

The 30-kv high-voltage power supply is shown in its separate shielded chassis which includes its own low-voltage power supply. The unit operates on the r-f principle and develops the 30 kv by means of a voltage tripler circuit. The energy storage capacity is represented in effective shunt capacitance of 250 $\mu\mu$m. This small capacitance in series with a one-megohm resistor materially reduces the danger of shock hazards. The unit has a current capacity larger than is necessary for the operation of the 5TP4 projection tube. A 5-kv tap is taken off from a potentiometer and is used for electrostatic focusing of the projection tube.

The remote video amplifier completes the system and makes it possible to operate the projection tube at distances up to 50 ft away from the receiver chassis without any detrimental effects upon the video signal due to the shunt capacitance of the projection tube. The gain supplied in this unit is sufficient to drive tubes having a higher second anode voltage than the 5TP4.

Today, receivers of this type are being used as a part of the Army Reserve Training Program. Similar models have also been used with marked success in conjunction with school programs, and modified versions are being submitted to the Navy for approval for use in some of its training and experimental programs.

Associated with the present demands for a more elaborate television system, it is felt that units in the near future will contain many of the considerations given in this paper.

# Designing Engine-Generator Equipment for Motion Picture Locations

By M. A. HANKINS and PETER MOLE

MOLE-RICHARDSON CO., HOLLYWOOD, CALIF.

SUMMARY: Artificial lighting on outdoor motion picture sets is essential for both day and night photography. In most cases an electrical distribution system is not available at the selected location, and power must be supplied by electric generators driven by internal-combustion engines. Because standard, commercially available, engine-generator sets are not suitable for the special performance requirements encountered in motion picture photography it is necessary to design and construct special equipment having the required features. This paper describes and evaluates the engineering factors involved, and illustrates how each of the desired characteristics was attained in equipment recently constructed.

## BASIC REQUIREMENTS

THE ENGINEERING FACTORS which must be considered in the design of engine-generator equipment for supplying electric power for lighting on motion picture locations are as follows:

*1. Electric Power.* The generated electric power should be 120-v, d-c, to supply satisfactorily both arc lamps, which require direct current, and incandescent lamps, which operate on either alternating or direct current. Experience has shown that engine-generator sets having a capacity of between 750 and 1,400 amp[1] will currently satisfy the load requirement in practically all cases, with those at or near the higher rating being more in demand. The increase in the number of color pictures being made on locations indicates a possible future demand for engine-generator sets having capacities above 1,400 amp, and a few sets capable of producing 2,000 to 2,500 amp have been constructed. However, in considering the feasibility of these larger units the advantage of increased capacity must be weighed against the disadvantage of decreased portability due to added size and weight. Also the relatively fewer occasions on which they can be used should be considered. To date, it has been generally accepted that it is more feasible to use two or more smaller, lighter, and hence more maneuverable, engine-generator sets to supply the higher current demands on location.

A three-wire d-c system is superior to a two-wire system for distrib-

uting large amounts of power.[2]   A three-wire system produced by a single three-wire generator is not well suited for motion picture work because of the inherent variation in voltage caused by load unbalance, and such a system is best obtained by two generators connected in series.   Driving two generators from one engine presents mechanical problems.   When deciding upon the system to be used, the electrical advantages of the three-wire system should be weighed against the necessary mechanical complications required to produce it, and the decision is usually determined by the power rating.   For engine-generator sets of capacities up to 1,400 amp which are to be driven by a single engine, experience has shown that it is better to use one two-wire generator and accept the disadvantages of the resulting two-wire distribution system.   However, when considering larger loads up to 2,500 amp, the electrical advantage of the three-wire system becomes the governing factor, and a construction having two 120-v generators in series is to be preferred.   Such plants should have two engines, one for each generator, thereby gaining an advantage in the form of flexibility, in that only one engine need be operated when the plant is supplying half-load or less.

Good, consistent lighting is dependent upon close control of the voltage at the load-end of feeder cables.   The lighting load encountered on locations varies from a small fraction of the generator rating up to its maximum capacity.   Feeder cables may be short or relatively long, dependent upon the conditions at the location.   An appreciable increase in voltage cannot be tolerated because of the danger of damaging incandescent lamp filaments.   Automatic voltage regulation to meet these operating conditions is essential.

Commutator ripple in the d-c voltage causes noise emission from carbon arcs which can be objectionable on sound sets.   Generators for motion picture work should be so designed that their ripple voltage does not exceed $\pm$ $\frac{1}{2}$ of 1% of rated voltage.   Even then the ripple is, on many occasions, further reduced by means of filter circuits using choke coils and capacitors.[3]

Since the duty cycle of an engine-generator set is of an intermittent nature, a generator which will produce the required maximum amount of power for approximately one-half hour without injurious heating is considered to be adequate.   Hence, much smaller and lighter weight generators can be used than would be the case if it were necessary to give them a continuous rating at the maximum output.

2. *Prime Mover*. Either a gasoline or diesel engine can be used to drive the generator and both types have been successfully employed.   The speed–power curve of the engine should match the

generator requirements, bearing in mind that, as a protective measure, engine horsepower should be somewhat below that capable of driving the generator at an injurious load.

The engine should be equipped with a governor capable of manual adjustment to maintain automatically any desired speed within the generator operating range.

*3. Control.* The controls for both the engine and generator should be conveniently grouped so a single operator can quickly perform all operating functions required.

*4. Noise.* On sound locations the engine-generator set must be positioned so that its operation noise does not interfere with production. A design which effectively reduces the noise level saves setup time and permits the use of shorter feeder cables since the plant can be located closer to the action.

*5. Portability.* The engine-generator set should be as small and light in weight as possible. Its dimensions should allow passage through door-openings in railway cars, and be suitable for mounting on a truck or trailer. Maneuverability in and out of "tight spots" on locations is essential.

*6. Dependability.* More often than not, engine-generator sets operate in remote locations where supply parts and the repair-shop type of maintenance service are not available. A breakdown on such locations would hold up an entire company and increase production costs. For that reason the construction should be as foolproof as possible, using the minimum number of parts to satisfy operational requirements. The components employed should be of a standard commercial type which have proven their reliability under service conditions.

*7. Protective Devices.* Automatic-operating safety devices should be incorporated to protect the engine-generator set against damage caused by abnormal conditions.

*8. Maintenance.* The use of standard, readily available, commercially proven components greatly reduces the maintenance problem. In addition, the engine-generator set should be designed so that those parts which require periodic maintenance are readily accessible.

## ATTAINING THE REQUIREMENTS

In order to illustrate methods which may be employed to meet the foregoing basic requirements, a particular design of a 150-kw engine-generator set recently manufactured by the Mole-Richardson Co. is described. The completed unit (Figs. 1 and 2) consists of a cubicle

EXHAUST STACK (REMOVABLE)

MUFFLER COMPARTMENT DOOR — TOP LOUVER DOOR

CARBURETOR AIR — CONTROL PANEL
INTAKE BAFFLE CAP
(REMOVABLE) — RADIATOR

MAIN BASE FRAME — BUS BAR PANEL

ENGINE COMPARTMENT — GENERATOR COMPARTMENT
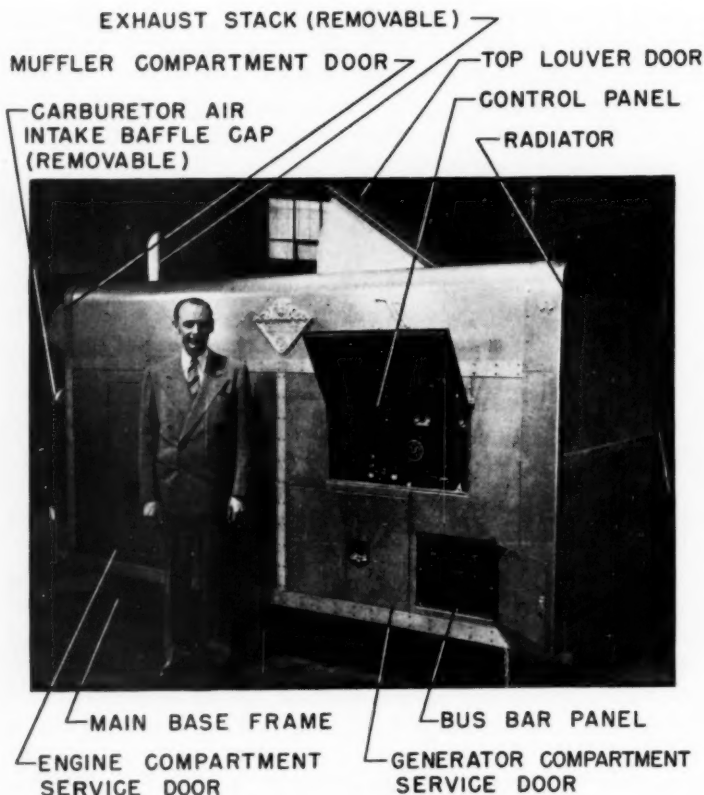SERVICE DOOR                    SERVICE DOOR

Fig. 1. 150 Kw engine-generator set.

54 in. wide by 72 in. high by 118 in. long and weighs approximately 10,000 lb. The enclosure forms the outside walls of three separate internal compartments: the generator compartment at the radiator end of the plant, the engine compartment at the rear of the plant and the muffler compartment at the top. All outer surfaces of the housing are polished, stainless steel. The design features directly related to the basic requirements are described as follows:

1. *Electric Power.* When contemplating the construction of a power-package, the electrical requirements and the engine must be simultaneously considered. Obviously, a special engine cannot be designed and built for this particular application, and one which will drive a generator of the approximate desired rating must be selected from those commercially available. Generator performance should
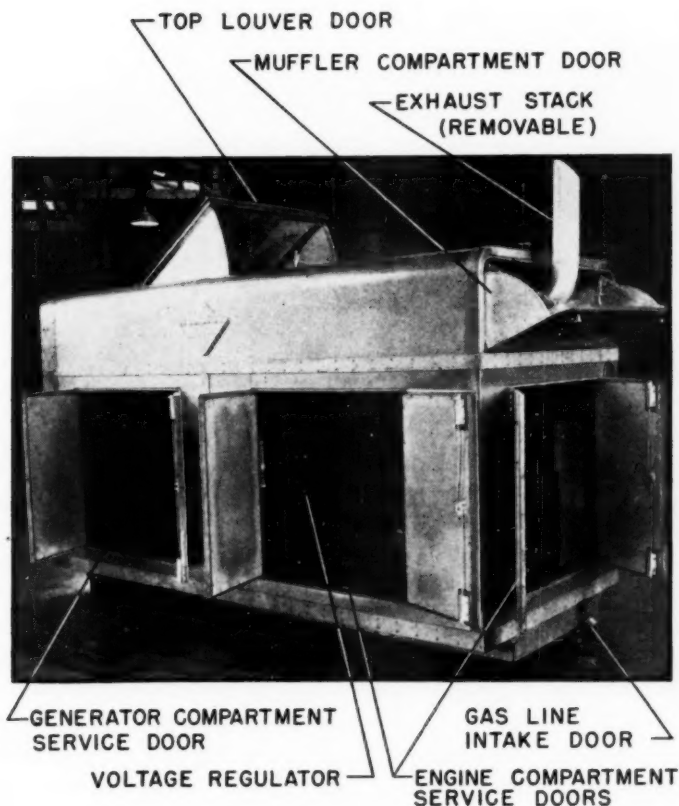
TOP LOUVER DOOR

MUFFLER COMPARTMENT DOOR

EXHAUST STACK
(REMOVABLE)

GENERATOR COMPARTMENT
SERVICE DOOR

GAS LINE
INTAKE DOOR

VOLTAGE REGULATOR

ENGINE COMPARTMENT
SERVICE DOORS

Fig. 2. Oblique view, off-side and rear.

conform to the speed–horsepower characteristics of the chosen engine, and modification of standard generator design is generally required.

In this instance, after consideration of available engines, it was decided to construct equipment capable of delivering 1,200 amp at 125 v, or 150 kw. To meet this requirement, a generator (Fig. 3) was chosen which has an intermittent duty rating of 1,400 amp, 125 v at 1,800 rpm, and a continuous rating of 1,000 amp, 125 v at 1,400 rpm. It will pick up its voltage at 1,350 rpm without exceeding rated field current. The voltage rating allows for a 5-v line drop when maintaining 120 v at the load-end of feeder cables. The generator is two-wire, self-excited, flat compounded, Class B insulated, and weighs approximately 2,500 lb. Its voltage ripple characteristic is within the allowable limit of $\pm \frac{1}{2}$ of 1% of rated voltage. An automatic

ENGINE        GENERATOR
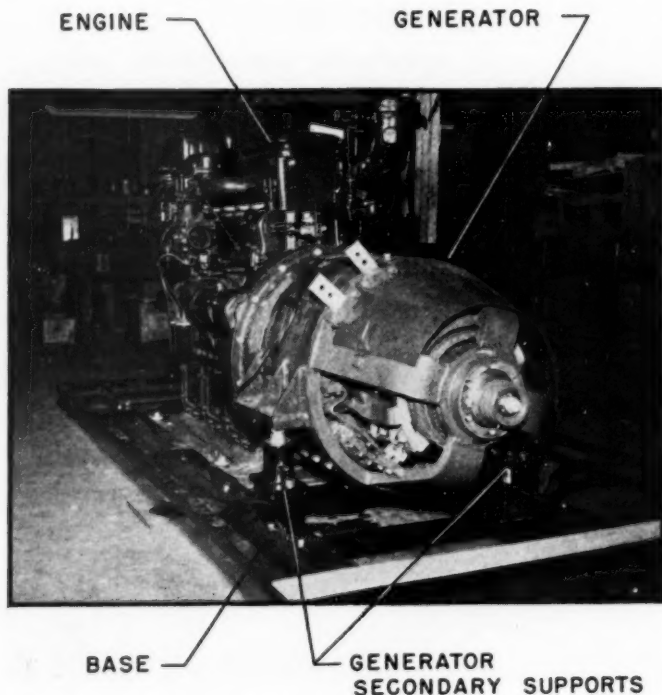


BASE        GENERATOR
SECONDARY SUPPORTS

Fig. 3.  Engine-generator assembly.

voltage regulator, located as shown in Fig. 2, maintains the proper
voltage setting over the speed range of the generator.  A field con-
trol rheostat is provided so that voltage can be manually controlled
in case trouble should develop with automatic voltage regulation.
A field control switch at the control panel permits the operator to
select the type of voltage regulation desired.

2. *Prime Mover.*  The engine (Fig. 4) selected for this application
develops 275 hp at 1,800 rpm as shown by its speed–horsepower
curve (Fig. 5).  After allowance is made for the power consumed by
auxiliary drives, the engine is nearly fully loaded by 150-kw generator
output at 1,800 rpm.  Likewise, the engine power-input conforms to
generator power-output at 1,400 rpm.  The load current can there-
fore be increased from 1,000 amp at 1,400 rpm to 1,200 amp at 1,800
rpm at a rate of about 50 amp for each additional 100 rpm.  This is a
desirable feature since there is no need to operate the engine at a
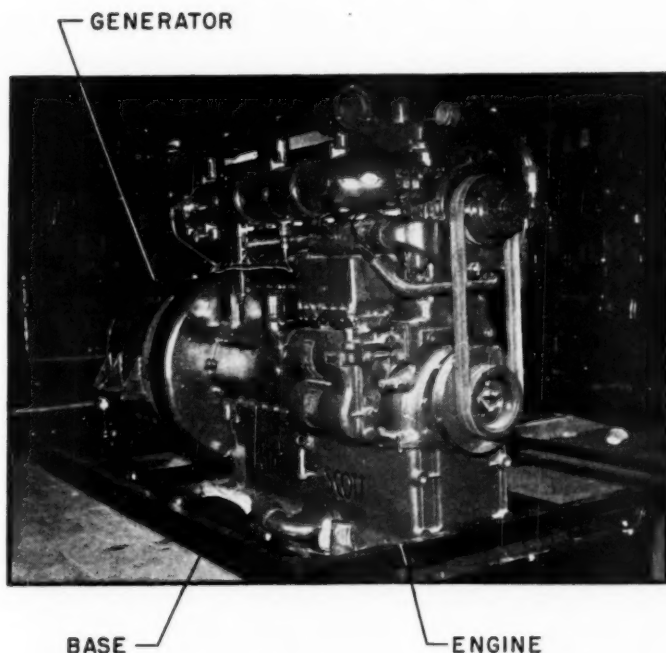speed higher than necessary to develop the required horsepower.

Fig. 4. Engine-generator assembly.

The engine is of the industrial type having six cylinders with a bore of $5\frac{3}{4}$ in., a 7-in. stroke, a displacement of 1,090 cu in., a compression ratio of 5.7 to 1, and a weight of approximately 2,600 lb. It is designed to consume ethyl gasoline fuel having an octane rating of approximately 80.

This engine is equipped at the factory with a governor adjusted to maintain an engine-operating speed of 1,400 rpm. The tension of an added external governor spring is varied by a knob at the control panel so engine speed can be adjusted above that which would otherwise be maintained by the governor proper. This allows the operator manually to adjust the automatic governor over the rated speed range of 1,400 to 1,800 rpm.

The generator end bell is designed to flange mount with a rabbet fit to the flywheel bell housing of the engine. The special resilient-type coupling (Fig. 6) is designed for connecting the generator shaft to the engine flywheel. The flywheel is modified to accommodate its portion of the coupling. This type of construction results in a mini-

mum of runout between the axis of rotation of the engine crankshaft and that of the generator armature and, therefore, insures long trouble-free coupling life. Mounting the generator direct to the engine bell housing results in a minimum over-all length of the coupled units.

The engine and generator coupled to form one integral unit are mounted to the main-base frame primarily by means of the industrial
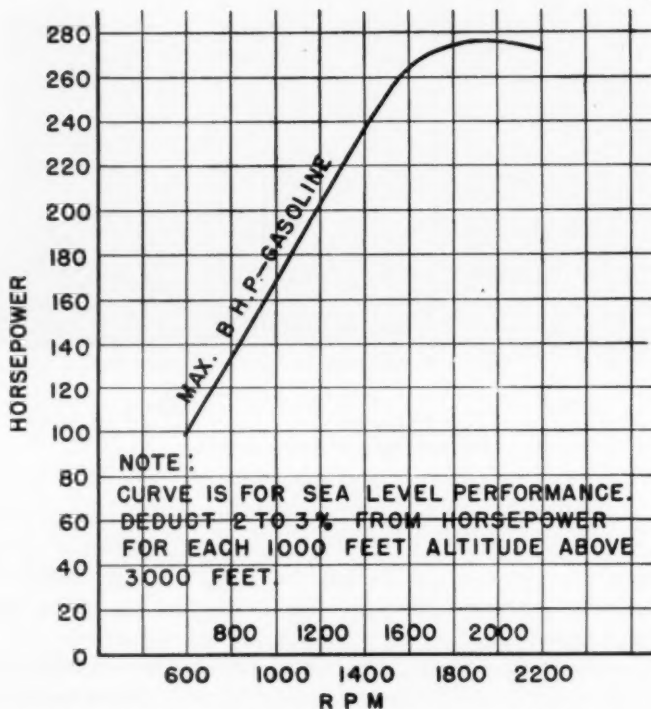


Fig. 5. Speed–horsepower curve for Hall-Scott model 400-0 engine.

base of the engine (Figs. 3 and 4). Thick rubber belting under the engine base and rubber bushings and washers at the holddown bolts prevent metal-to-metal contact between the engine and the main-base frame, minimizing the transmission of engine vibrations to the power plant structural members. Since the generator is an overhung weight mounted to the engine bell housing, secondary supports consisting of rubber tube-form mountings (Fig. 3), are positioned between the main-base frame and the ears of the generator with their upward

COUPLING LINKS
ON FLYWHEEL

GENERATOR
MOUNTING FLANGE

FLYWHEEL



ENGINE FLYWHEEL
BELL HOUSING

COUPLING PINS IN
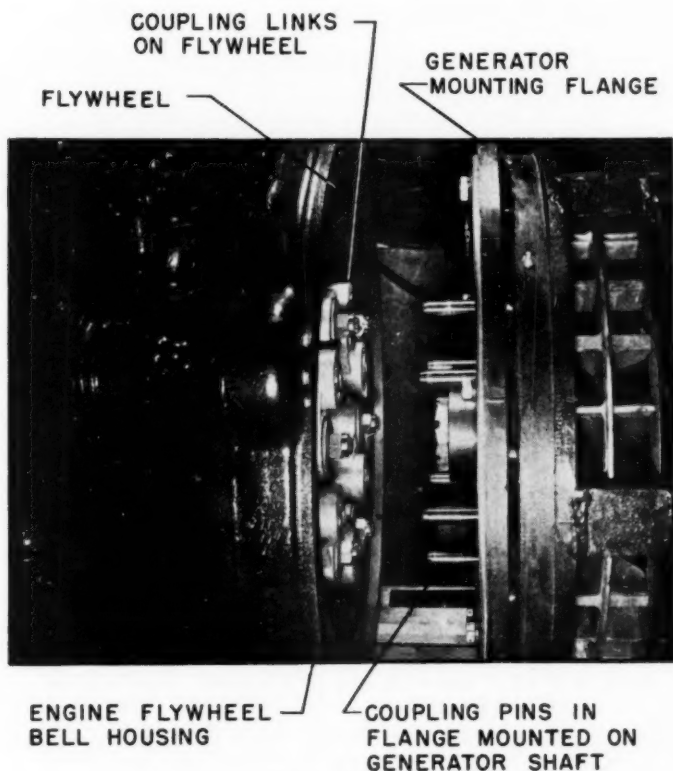FLANGE MOUNTED ON
GENERATOR SHAFT

Fig. 6. Coupling.

thrust forces evenly adjusted for minimum strain on the engine bell-housing. Here again, there is no metal-to-metal contact with the main-base frame.

*3. Control.* All operating controls and adjustments of the engine-generator set are located on the control panel shown in Fig. 1 and illustrated in detail in Fig. 7. The controls and instruments are divided into two groups: the engine controls on the left and the electrical controls on the right.

*4. Noise.* The major portion of operational noise of an engine-generator set consists of engine mechanical noise, exhaust noise, radiator fan and cooling air noise, and carburetor-intake noise.

As described above, the engine and generator are resiliently mounted so there is no metal-to-metal contact with the structural members of the unit, thus minimizing the transmission of engine vi-

ENGINE CONTROLS          |          ELEC. CONTROLS

VACUUM GAGE ─┐ | ┌─ VOLTMETER
WATER TEMPERATURE GAGE ─┐ |
TACHOMETER─┐ | ┌─MANUAL FIELD
BATTERY AMMETER &─┐ | CONTROL RHEOSTAT
OIL PRESSURE GAGE
GASOLINE PRESSURE GAGE─┐ | ┌─OVERLOAD RELAY
MANUAL FAN PITCH ─┐ | RESET BUTTON
CONTROL LEVERS
GOVERNOR CONTROL ─┐ | ┌─AMMETER

HAND THROTTLE─┐ | ┌─FIELD CONTROL
CHOKE CONTROL─┘ | SELECTOR SWITCH
ELEC. FUEL PUMP SWITCH─┘ | ┌─VOLTAGE REGULATOR
DUAL IGNITION SWITCHES─┘ | ADJUSTMENT RHEOSTATS
IGNITION KEY SWITCH ─┘ | ┌─LINE CONTACTOR
LIGHT SWITCH ─┘ | PUSH BUTTON STATION
STARTER PUSH BUTTON SWITCH─┘ | ┌─VOLTAGE REGULATOR
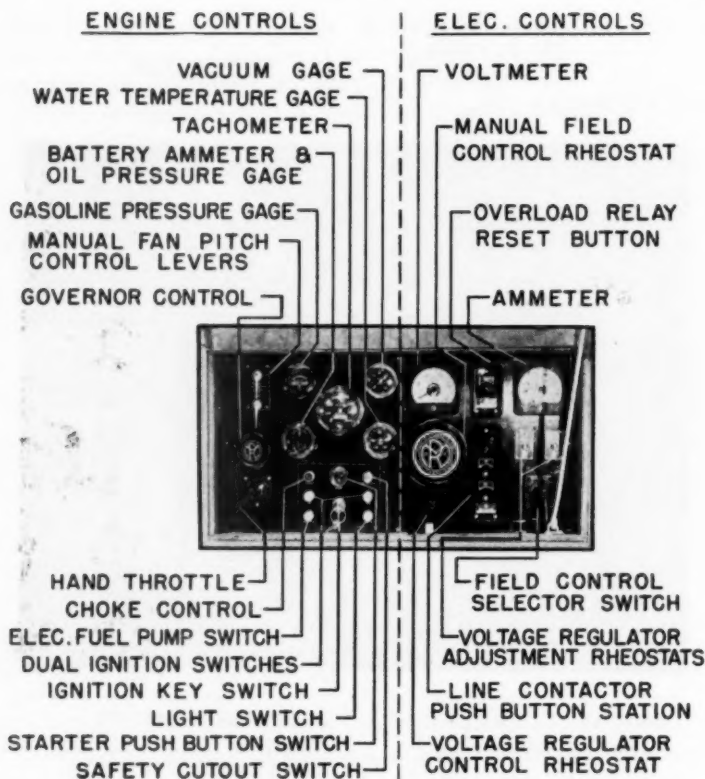SAFETY CUTOUT SWITCH─┘ | CONTROL RHEOSTAT

Fig. 7. Control panel.

brations to the housing. The engine is completely enclosed by the engine compartment, the walls of which are insulated against sound transmission. The wall construction consists of the following, enumerated in order of position from outside to inside: stainless steel sheet, sound-deadening undercoating, air space, sound-deadening undercoating, asphalt compound, fiber glass insulation, fiber glass cloth and perforated stainless steel sheet. (Since the engine is completely enclosed, cooling is dependent entirely upon the water-cooling system.)

The exhaust noise is reduced by a large muffler 14 in. in diameter by 6 ft long, mounted in the muffler compartment above the engine compartment. The walls of the muffler compartment are also insulated against sound transmission in the manner described above.

FAN ⌐      ⌐ FIELD RHEOSTAT
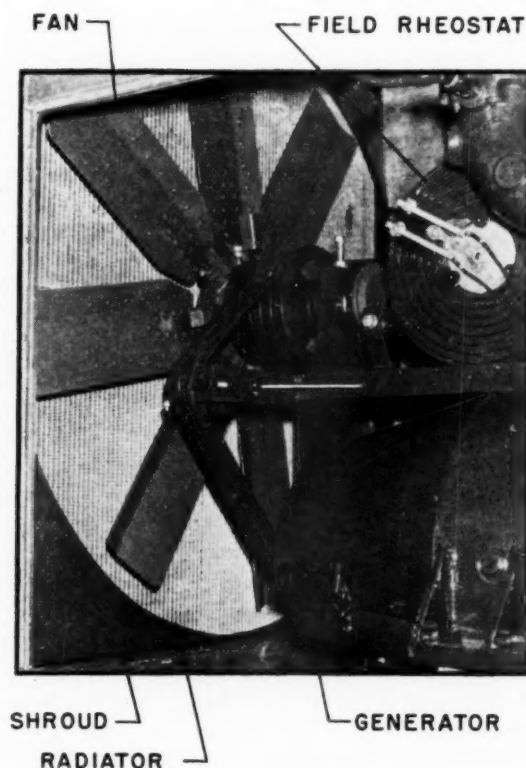
SHROUD ⌐      ⌐ GENERATOR
RADIATOR ⌐

Fig. 8. View through off-side generator
compartment service door.

A right-angle exhaust stack (Figs. 1 and 2) directs the exhaust gases in an upward direction.

The attainment of adequate engine cooling with a minimum noise from fan and air flow is primarily accomplished with the use of a radiator having an exceptionally large frontal area (Figs. 1 and 8). The radiator has approximately twice the capacity of those normally used in industrial applications of this engine thereby providing sufficient cooling with a relatively low air speed. This radiator also permits the use of a large 48-in. diameter, 8-blade fan (Fig. 8) which can provide the required rate of air flow at a low top-speed of 740 rpm. The fan is belt-driven from a sheave on a shaft extension at the commutator end of the generator.

A further reduction of fan and air noise is obtained by the use of a variable-fan-blade-pitch control system which automatically controls the pitch of the blades in accordance with the cooling-water temperature; thus no more air is passed through the radiator than is necessary. A manual control of the pitch of the fan blades permits the operator temporarily to feather the blades to zero pitch and stop the air flow, and the resultant noise, during a "take."

The cooling air, after being drawn through the radiator, passes through the generator compartment and is exhausted through the muffler compartment door, and top louver-door whose opening can be adjusted. On many occasions the power plant can be operated with the top louver-door closed, with all of the cooling air passing through the muffler compartment and exhausted upward at the rear of the plant. All walls of the housing are insulated, as explained for the engine compartment, and therefore are deadened against vibrations caused by air flow.

The carburetor-intake noise cannot be neglected. In this application outside air is drawn in through a baffled cap (Fig. 1), then through a large industrial-type air cleaner (Fig. 9), and into the carburetor. The baffled cap and air cleaner function as silencers.

*5. Portability.* The minimum over-all engine-generator set dimensions result from the following considerations: The 54-in. width accommodates a radiator having the desired capacity and in addition provides adequate clearance between the inside walls of the housing and the internal components for service and maintenance accessibility. The minimum height is determined on one end by a radiator of sufficient capacity, and on the other end by the combined heights of the engine and muffler. To reduce the latter, the engine mounting platform, consisting of steel channels welded crosswise and longitudinally, is recessed below the top surface of the main-base channel structure. Thus the minimum height requirement for the engine and muffler is made to conform to that required for the radiator. The length of the power plant is considerably reduced by the design of the short-coupled arrangement between the engine and the generator.

Such engine-generator set cubicles are either carried on trucks or trailers. In the design of this plant, the 54-in. width of the enclosure is reduced by a curved contour near its base to 33¾ in., which is slightly less than the standard 34-in. over-all width of the main frame of commercial trucks having the capacity to carry this power plant. The 9¼-in. height above the bottom surface of the main base to the point where the power plant enclosure becomes 54 in. wide provides clearance over the rear wheels of the standard commercial trucks.
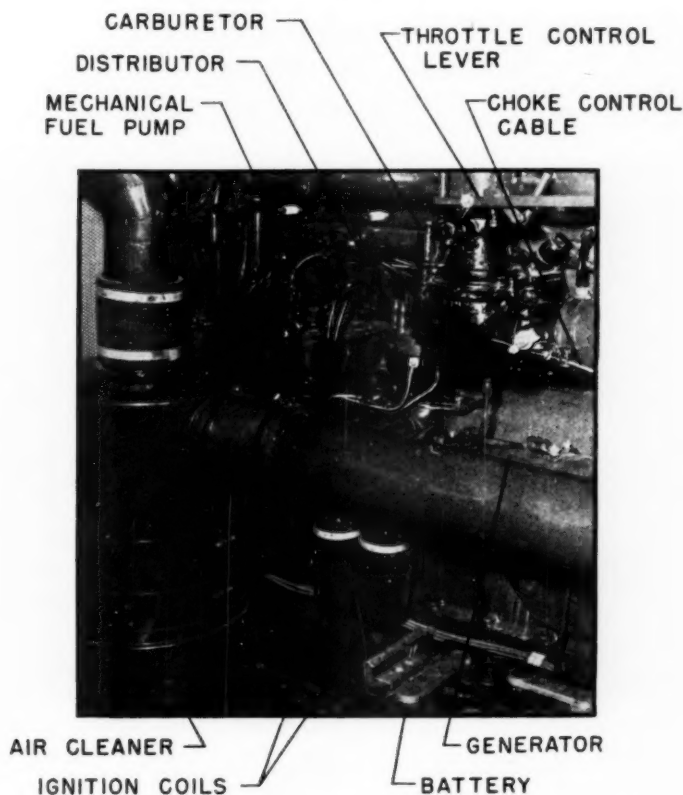
Fig. 9. View through engine compartment service door on operator's side.

This allows the power plant to be positioned low between the rear truck wheels, hence resulting in a minimum over-all height, and a minimum height of the center of gravity of the power plant above the ground. This same design feature is equally advantageous if the cubicle is to be mounted on a trailer.

Arrangements are provided for handling the cubicle as a unit. Heavy steel tubular members are welded crosswise through the main-base frame near the front and rear and other tubular openings are located at both ends. These tubular openings are for insertion of heavy steel handling bars or wheel axles.

6. *Dependability*. Dependability is necessary for trouble-free operation of all components. The engine chosen for this application is one which has proven its dependability in years of truck service, bus serv-

HOUSE PLUG RECEPTACLE

TWIST LOCK RECEPTACLE

STAGE POCKETS
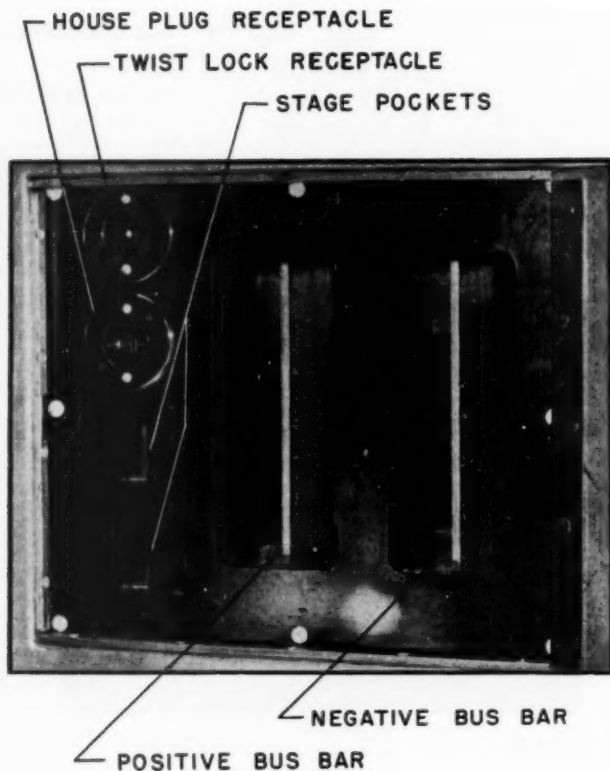
NEGATIVE BUS BAR

POSITIVE BUS BAR

Fig. 10. Bus bar panel.

ice, in oil field locations and in other industrial applications. The generator is of a rugged design which has performed successfully in railway transportation equipment. The method used in coupling the generator to the engine insures long coupling life.

Wherever practical, automatic operating components are supplemented by manual controls to reduce the possibility of shut-down. The automatic voltage regulator is supplemented by manual field rheostat control. The pitch of the fan blades can be manually controlled in case of failure of automatic control. Should manual control become inoperative, the blades can be mechanically locked in their pitched position and operation continued.

There are, of course, inevitable possibilities of failure of equipment which could cause shut-down. The best insurance against such
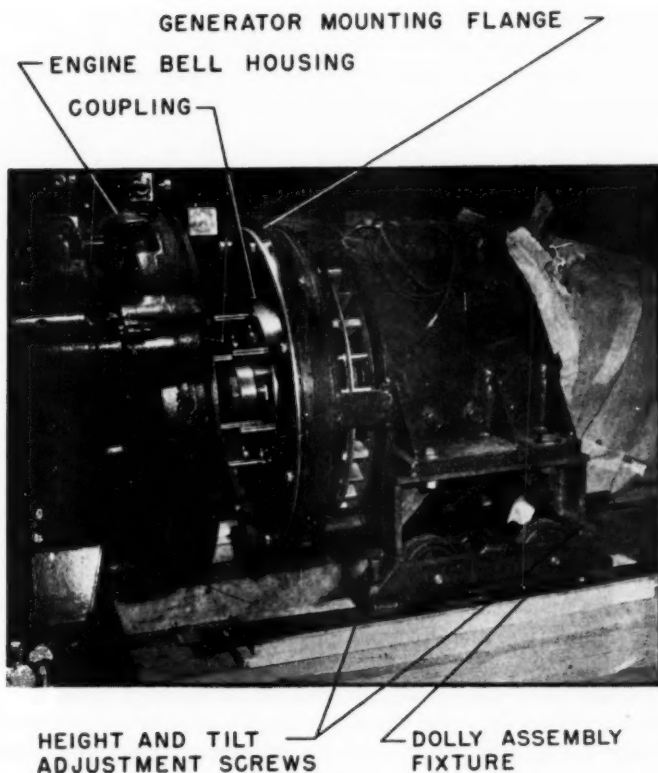
GENERATOR MOUNTING FLANGE

ENGINE BELL HOUSING

COUPLING

HEIGHT AND TILT
ADJUSTMENT SCREWS

DOLLY ASSEMBLY
FIXTURE

Fig. 11. Generator on dolly fixtures.

occurrences is the use of components which have by service proven their reliability.

7. *Protective Devices.* An overspeed governor, coupled to engine rotation, will open the ignition circuit and stop the engine before a damaging speed occurs. The engine cannot be restarted until the overspeed governor is manually reset by the operator.

A safety switch in the ignition circuit will stop the engine if a loss of oil pressure occurs, or if the cooling-water temperature becomes too high.

An overload relay, which will open the main line contactor, protects the generator against overloads.

The positive battery cable is grounded through a pin-plug arrangement so it can be conveniently and positively removed as a safety

precaution during servicing, or when the power plant is idle. All battery circuits, except the starter motor circuit, are fused.

A Thyrite discharge resistor, permanently connected across the generator shunt field, protects the field insulation against high voltage breakdown by limiting the induced voltage which momentarily appears when the field circuit is opened.

The positive and negative bus bars for external feeder-cable lug connections (Fig. 10) are recessed behind an insulation panel, and an insulation barrier is located between them for protection against short circuits. The convenience outlets at the left of the bus bars are fused.

8. *Maintenance.* Door openings in the enclosure are such that all components are accessible for routine maintenance. The housing is constructed in sections to provide access for general overhaul. The top section, or muffler compartment, is removable as a unit. Each of the sides consists of two separate wall panels, and the rear is made up of one panel, all of which are individually removable. External stainless steel trim strips not only serve to cover the joints between sections for the sake of appearance, but also as mechanical members which tie the housing sections together.

During a major overhaul of the power plant it may become necessary to detach the generator from the engine bell housing and separate the coupling. Adjustable dolly fixtures are provided (Fig. 11) which can be secured to the ears of the generator in place of the secondary supports. With the dolly wheels resting on the main base channels, the generator may be rolled in or out of engagement with the engine.

## CONCLUSION

In the making of motion pictures the production-time factor is of such importance that every precaution against possible power failure should be given the utmost consideration. The engine-generator set must be sufficiently rugged to withstand hard travel over rough roads, yet deliver the maximum of power with constant performance. In spite of the fact that it is a highly specialized piece of equipment, it should, so far as possible, be designed for, and constructed of, units which have been proven dependable in other fields.

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2. "Report of Studio-Lighting Committee," *Jour. SMPE*, vol. 49, pp. 279–288, Sept. 1947.
3. B. F. Miller, "A motion picture arc-lighting generator filter," *Jour. SMPE*, vol. 41, pp. 367–373, Nov. 1943.

# Laboratory Practice Committee Report

By JOHN G. STOTT, Committee Chairman

IN THE FALL OF 1948, the writer proposed to John A. Maurer, then Engineering Vice-President of the Society, that a committee on chemical engineering practice be organized to provide Society members with much needed information on chemical and chemical engineering practice as it applies to our industry. Mr. Maurer agreed with the proposal and suggested that such a committee be organized as a subcommittee of the Laboratory Practice Committee. A subcommittee composed largely of chemists and chemical engineers working in the motion picture industry was accordingly appointed. Later it was suggested that this subcommittee expand its activities to include the entire function of the parent Laboratory Practice Committee under its present chairman. The committee was organized with East Coast and West Coast Sections, the West Coast Section under the co-chairmanship of Vaughn Shaner.

It was still intended that the parent committee would work primarily on chemical and chemical engineering problems as they relate to the motion picture industry. However, at the first meeting of the Committee held in New York City the members brought up so many other laboratory problems that the original objective concerning chemical problems was placed far down the agenda laid out at that meeting. Another meeting of the Committee was held in Hollywood during the Fall Convention of 1949 at which time the projects laid out by the East Coast Group were discussed and other projects added to the agenda. The complete proposed agenda came to be as follows:

1. Design of a special leader for television films to replace the Academy theater leader.

2. Aid in the standardization of screen brightness for 16-mm projection.

3. Establish a standard for the notching of 35-mm and 16-mm negative films.

4. Investigate the possibility of modifying sound and picture reduction printers to print forward and backward, and to employ 2000-ft negative feed and take-up.

5. Investigate the standardization of edge numbering of 16-mm.

6. Study recommendations for the splicing of 16-mm films.

7. Study recommendations regarding 16-mm projection emulsion position.

8. Study methods of bringing data on chemical and chemical engineering developments to the attention of Society members.

Other laboratory problems were discussed, but were tabled as either being under the jurisdiction of other Committees of the Society or entirely outside the sphere of activity of the Society.

The third meeting was held in New York. At that meeting V. D. Armstrong was appointed as the Laboratory Practice Committee representative on the Films for Television Committee which is undertaking the design of a television leader; therefore Mr. Armstrong is functioning in an advisory capacity to that Committee on any television leader production or use problems as they concern the motion picture laboratory. A report on this leader is forthcoming from this Committee.

Edward Cantor was appointed to make a cursory survey of 16-mm screen brightness presently used in New York, Midwest and Hollywood laboratories for print examination. It was felt that this would represent a first move toward a recommended screen brightness of 16-mm projection. When completed, these data will be submitted to the Screen Brightness Committee for their use in further studies.

Also, at the third meeting the Chairman was instructed to write to manufacturers of sound and picture reduction printers suggesting that they design these printers for forward and backward printing and provide facilities for printing from 2000-ft negatives. At the present writing the response from the printer manufacturers indicates no particular problem on the 2000-ft negative feature, but opinion is unanimous that the forward and backward printing feature would entail expensive design changes. Further examination of this project will be made.

Paul Kaufman was appointed to study recommendations for the notching of 35-mm and 16-mm negatives. This study has progressed satisfactorily, and a tentative standard for 35-mm will be proposed shortly. However, the 16-mm notching problem is going to be more difficult to resolve. It has been suggested by Lloyd Thompson that, in view of the present confusion and nonuniformity in 16-mm notching, an entirely new scene exposure changing system be adopted as a standard. Mr. Thompson has suggested that a magnetic cue system be used, which will eliminate the need for an actual notch in the film. This proposal will be considered in subsequent meetings.

The 40-frame edge numbering proposal for 16-mm was originally opposed because of the laboratory problem of picking replacements on 16-mm printed from 35-mm. When the proposed standard offering the optional privilege of edge numbering at the 40-frame interval or not edge numbering at all was submitted to the Committee, this original objection was withdrawn. It was felt that 16-mm replace-

ment from 35-mm preprint material could be picked by scene description as has been done in the past. Realizing that a 16-mm edge numbering standard was badly needed, it was agreed that any further complication of the 16-mm edge numbering situation by the Committee would be detrimental to the 16-mm industry.

The Committee has gone on record as opposing any change in the present 16-mm standard for emulsion position during projection. The laboratories printing 16-mm from 35-mm preprint material, which is by far the greatest dollar volume of product, end up with film projecting according to the present standard. Any change in 16-mm projection standards would require extensive and expensive alterations in existing printers, etc. It was felt that a change in 16-mm projection standards would impose severe economic hardship on the laboratory, greatly out of proportion to the benefit that would accrue to other film-using segments of the industry.

Thus far, no work has been done in the splicing of 16-mm films.

A fourth meeting of the Committee was held also in New York. At this meeting Mr. Cantor reported on the 16-mm screen brightness survey of New York laboratories. The survey of Midwest and Hollywood laboratories is yet to be made.

At this meeting the chemical and chemical engineering problems were again discussed. Irving Ewig was appointed to start some work on these problems. Mr. Ewig is to make a survey of chemical and chemical engineering magazines and journals having data of interest to our industry. The Committee has requested that the Society subscribe to several periodicals to be submitted to committee members for abstracting. The Committee has also requested of Clyde Keith, Editorial Vice-President, that JOURNAL space be made available for publishing these abstracts to benefit all Society members. This was approved by Mr. Keith. Fred Bowditch, Engineering Vice-President, has authorized the reforming of a subcommittee on chemical engineering practice within the Laboratory Practice Committee. Hence, the original organization plan of the Committee has been realized.

A fifth meeting of the Committee was held at the 1950 Spring Convention in Chicago. At this meeting the afore-mentioned projects were discussed briefly and a long discussion ensued with representatives of the Armed Services on the 16-mm projection screen brightness problem. Further help on this problem has been offered by the Armed Services in an effort to arrive at a suitable standard for 16-mm screen brightness.

# 68th Convention

Feature items on the Papers Program include a Symposium on Film Registration that will appeal particularly to designers of film handling equipment. Recent study of film perforation shape as it affects steadiness in the camera, registration in printing and projection life of release prints will be reported upon at length. The years of formal experience with film perforated to current standards, together with surveys now under way, should provide a thorough engineering basis for proposed new film standards that will be of serious interest to all film, equipment and laboratory people.

Most of one day will be devoted to papers on several application aspects of high-speed motion picture photography. Adequate time is to be allowed for discussion from the floor of practical application problems.

Editing magnetic sound tracks in motion picture studio production will highlight another session and tie in with papers on magnetic recording equipment and studio practices.

Photographic sound recording on a new type of color motion picture release film will be discussed as will many other items of interest, including "T" stop calibration of camera lenses.

— *the place* is Lake Placid Club — *the time* is October 16–20 — *reservations* are now being accepted, so send the card you received recently (or write) to: Daniel Nelson, Reservations Manager, Lake Placid Club, Lake Placid, N.Y. — *families* are more than welcome — *informality* prevails — *you and your guests* will enjoy the outdoor recreation.

Members going to Lake Placid from the West should take the New York Central and change at Utica. Those from New York City, the South or areas connecting only with the Pennsylvania Railroad can arrange for overnight or day service from New York City directly to Lake Placid via the New York Central.

Air transportation from New York City can be made available on a charter basis provided there are enough reservations. Planes are tentatively scheduled to leave New York at 10 A.M. and 2 P.M. Sunday, October 15, and 10 A.M. Monday, October 16, with return flights leaving Lake Placid at 10 A.M., 2 P.M. and 6 P.M. Friday, October 20. Round-trip fare is $40.00. If you desire a reservation on the plane, your check must be received by Society Headquarters before September 10. Please indicate your preference for departure times.


# Board of Governors

On Wednesday, July 26, the Society's Board of Governors met for its third regular meeting in 1950. Fiscal affairs were discussed at length and the Board reports that, in general, operations for the first half-year compare very favorably with the budget estimate. One disappointing note, however, was the report on membership status which showed dues for nearly 10% of the entire membership still unpaid as of June 30. The Board is investigating the reasons for this heavy list of delinquents, so that appropriate steps can be taken to reinstate them, as well as to avoid a long list of delinquents next year.

Candidates for Society offices selected by the Nominating Committee for the annual fall election were ratified by the Board as were nominees for Journal

Award, Samuel L. Warner Memorial Award, SMPTE Progress Medal Award and Honorary memberships.

Having been away from motion picture activities for a number of years, Louis Pacent had resigned from membership in the Society. He now plans to renew his interest in technical motion picture matters and his reinstatement as a Fellow received unanimous endorsement by the Board.

Student chapters of University of Southern California and New York University have both been active recently. To help them along the Board has appointed Loren L. Ryder and William H. Rivers as Society advisers.

# Engineering Committees

The summer months in recent years have been periods of relative inactivity for the Society's engineering committees, but the current load of standards projects and work related closely to television has kept several committees working diligently throughout the vacation season. Here, briefly, are two items of interest.

### Theater Television

Under the Chairmanship of D. E. Hyndman, the Theater Television Committee's detailed study of performance requirements for interconnecting facilities will be continued with an examination of the effects of bandwidth variations, signal-noise ratio, distortion and compression on quality of the projected theater television picture.

Representatives of the common carriers, as well as manufacturers of equipment for this new industry, have taken an active part and have highly praised the efforts of Otto Schade in his study of the four fundamental characteristics. Work on bandwidth requirements has progressed very well. A figure for admissible random noise has been proposed, based upon a detailed and objective sampling procedure developed by Mr. Schade, using the "noise" level of motion picture film as a reference. Subjective comparison of the experimental results between film and television pictures has already been made on a limited scale and will be repeated again, using full-scale commercial equipment for both pictures in the near future.

Tentative conclusions have been made concerning square-wave distortion limits. Further work is now being done and will soon be discussed by the Committee.

### Screen Brightness

For more than fifteen years, considerable time and effort have been devoted to the well-organized programs of the Screen Brightness Committee, work having begun seriously in the early thirties. A comparison method of estimating screen reflectivity was adopted, and sample gray cards to serve as reflection factor standards were bound into the JOURNAL for June 1933. Extended study of print density, vision and screen illumination produced a series of JOURNAL articles in the mid-thirties.

Measurement methods have always been a serious problem. Just before the last war the Committee, under Frank Carlson, began to develop a photoelectric screen brightness meter, but the press of other urgent matters stopped the program shortly after a specification was agreed on. Three years ago the project was revived under the joint guidance of Erwin Geib and Bob Zavesky. A preliminary

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survey of eighteen theaters was encouraging and set the stage for an extended program by serving as a proving ground for several types of instruments, as well as providing a review of survey procedures. The Committee has now completed plans to start work on a somewhat larger survey of an estimated one hundred theaters ranging from small houses having fewer than five hundred seats to the largest in the country. Outdoor theaters and review rooms will also be included.

The screen brightness meter recently developed for the Committee by Allen Stimson of General Electric has been doubly checked for accuracy and will be used in succession by six survey teams. Cities included and team leaders are: Los Angeles, C. W. Handley; Chicago, C. E. Heppberger; Toledo, A. J. Hatch, Jr.; Rochester, F. J. Kolb, Jr.; Philadelphia, C. R. Underhill, Jr.; and New York, P. D. Ries. Considerable publicity for the survey has been given by the motion picture trade press, which will help to insure the co-operation of exhibitors and theater projectionists who were very generous with their time and assistance in the previous work.

# Letter to the Editor

I was very interested to read in the March issue of the JOURNAL the article on spontaneous ignition of decomposing cellulose nitrate film and the appendix on p. 381 on the film decomposition tests which have been carried out in this country [England].

There is, however, an error in the introduction to the latter, which I should be very grateful if you would correct.

The British Film Institute is described as "a Government Department similar to the U.S. National Archives." Although the British Film Institute, including its National Film Library, is maintained chiefly by a grant from H.M. Treasury, it is not a Government Department in the full sense of the term. The only Government Department concerned mainly with film preservation is that of the Government Cinematograph Adviser, at H.M. Stationery Office, which has in its care the films of the Imperial War Museum and those made by certain Government departments which are Crown copyright.

The National Film Library of the British Film Institute is the only other official body in this country concerned with the permanent preservation of films and film records. Our scope, however, is wider in that we are concerned with the film, not only as an historical record, but also as an art, and the greater part of our collection consists of nongovernment films. I imagine that whereas the Government Cinematograph Adviser's Department corresponds to the U.S. National Archives, the National Film Library here corresponds more nearly to the Library of Congress project which was in operation some years ago.

I hope that this clarifies the position. It is easy for confusion to arise because we co-operate most closely with the Government Cinematograph Adviser in all our preservation work and Mr. S. A. Ashmore, who advises the Government Cinematograph Adviser on technical matters, is also a member of our own Technical Committee. . . . .

ERNEST LINDGREN
Deputy Director and Curator
The British Film Institute

May 18, 1950

# Obituaries

**H. G. Christensen,** who was actively engaged in motion picture production since 1914, died in New York on June 10, at the age of 56. He was a native of Chicago and studied art before entering the field of training and sales-presentation and film production. During World War I he was one of the Army's first instructors in aerial photography, having been assigned to the U.S. Army School of Aerial Photography at Rochester, N.Y. During World War II he directed the filming of many training subjects, including such secret ones as radar. He had been President of the West Coast Sound Studios and Vice-President of the Associated Sales Co., in charge of its motion picture department some years ago. He directed over 130 short subjects for Universal and had filmed many commercial and industrial subjects. He was co-author with L. S. Metcalfe of *How to Use Talking Pictures in Business,* published by Harper in 1938.

**Lauriston Everett Clark,** 45, Director of Engineering for Technicolor Motion Picture Corp., died July 9, 1950, in Hollywood, Calif. Death was caused by a blood clot following an operation performed two weeks before. He was born at Haverhill, Mass., August 2, 1904, and attended the Massachusetts Institute of Technology. He served as an officer in the Chemical Warfare Reserve from 1925 to 1926. Previously associated with Radio Corporation of America and Dunning-color, Mr. Clark joined Technicolor on January 1, 1943. He had been a member of this Society since 1929 and was also a member of the Academy of Motion Picture Arts and Sciences and the Optical Society of America.

# Journals Needed

Motion picture technical books are being added to the cinema collection at Doheny Library, University of Southern California, and numerous issues of this Society's JOURNAL are needed to complete their reference file. Members who are willing to contribute any of those itemized below are asked to send a list of available copies to Boyce Nemec, Executive Secretary, so Society Headquarters can serve as a clearing house for all offers. In this way the Journals can be sent directly to USC without duplicating contributions or double handling of actual copies.

Under the Farmington Plan major libraries have been designated to collect publications from foreign countries on particular subjects, concentrating them at various locations within the United States. The University of Southern California has been designated the cinema center and consequently copies of every book on motion pictures published anywhere in the world will be sought for acquisition. Although official emphasis under this program is placed on books or pamphlets of foreign origin, USC also has a major interest in obtaining similar items which originate within the United States. The JOURNAL, being the industry's major technical reference source, is an important item in this latter group.

Issues currently missing from Doheny Library are:

TRANSACTIONS: Nos. 16, 18, 30, 31, and 35.

JOURNALS: Aug., Oct., Nov. and Dec. 1934; Mar., Sept. and Nov. 1938; Aug. and Dec. 1939; all months 1940; May and Aug. 1941; Apr. 1942; Sept. 1943; all months 1944; Aug. 1945; Dec. 1946; all months 1947; all months 1948; all months 1949; all months, to date, 1950.

# Central Section

The National Electronics Conference in Chicago September 25–27, joined this year by the Institute of Radio Engineer's Chicago Section on the event of their 25th Anniversary, will also have support of the Central Section of SMPTE. Technical Sessions of the three-day conference at Edgewater Beach Hotel include 63 papers on a wide variety of subjects, ranging on the technical side from microwave spectroscopy, magnetic amplifiers and hermetically sealed ion chambers to a philosophical contribution "Is the Engineer Slipping" by E. A. McFaul, formerly of Northwestern University. Over 100 industrial exhibitors will be on hand with equipment displays.

R. T. Van Niman, NEC Publicity Chairman and Past Chairman of the SMPTE Central Section, reports the NEC Television Session (10:00 A.M. Tuesday, September 26) will be the September meeting of the Section. Three papers scheduled are:

"Television in Industrial Applications," by J. A. Good, Diamond Power Specialty Corp.

"Stereo Television in Remote Control," by H. R. Johnson, C. A. Hermanson and H. L. Hull, Argonne National Laboratory.

"The Genlock: A New Tool for Better Programming in Television," by John H. Roe, RCA Victor Division.

All SMPTE members are invited to attend this and any of the other 17 sessions and three luncheon addresses by: Wayne Coy, Chairman of the Federal Communications Commission; Mr. McFaul, noted above; and John V. L. Hogan, President, Interstate Broadcasting Co., Inc., and Past-President of I.R.E.

Programs will soon be available from Mr. Van Niman.

# Book Reviews

## Film User Year Book, Volume II, 1950, edited by Bernard Dolman

Published (1950) by Current Affairs Ltd., "Film User" Office, 19 Charing Cross Rd., London, W.C. 2. 320 pp., including advtg. 5⅜ × 8⅜ in. Price, 10s. 6d.

The *Film User Year Book 1950* is a complete handbook of all the 16-mm and filmstrip activities in Great Britain for the year past. The various chapters deal with everything from projector placing diagrams and equipment to addresses to the British law in regard to the exhibitor.

All 16-mm film produced in the sponsored (commercial), entertainment, scientific and industrial, church and armed service fields is not only listed, together with the distributors' names and addresses, but also cross-indexed as to title and subject.

A complete census of film societies, distributors, producing companies, equipment manufacturers, recording studios, books and periodicals lists the names and addresses of practically everyone in the British Isles interested in any phase of motion pictures.

It is quite interesting to note that many major producers in the United States are releasing 16-mm prints of late hits through their British offices.

For the excellent data it contains, this book should be in the library of anyone interested in the British film industry.—WILLIAM K. AUGHENBAUGH, WLW-T, The Crosley Broadcasting Corp., Cincinnati, Ohio.

### The Organization of Industrial Scientific Research, by C. E. Kenneth Mees and John A. Leermakers

Published (1950) by McGraw-Hill, 330 W. 42 St., New York 18. 368 pp. + 15 pp. index. 20 figs. + 9 tables. 6 × 9 in. Price $5.00.

*The Organization of Industrial Scientific Research* is both a guide and a stimulus to the clear thinking that is so necessary to the organization and operation of a successful research laboratory. A study of this book will aid management in making wise decisions regarding the need for research and the appropriations for carrying it on. It will help those engaged in the direction and administration of research to improve the effectiveness of their laboratories. It will open new avenues of thought and understanding to the scientist who is beginning to be interested in, or confronted with, administrative problems.

While described as a "Revised Second Edition" (1st ed., 1920), this edition should be regarded as a new book with an excellent ancestor.

Part I presents the very interesting history and background of organized research in order to provide for an understanding of its present position, or status, in government, universities and industry. The amazing growth of research is outlined, together with ideas regarding the future.

Part II is concerned with existing research organizations. By example after example, by showing the needs, the accomplishments and the basic structures of organization, the present status of organized research is clearly presented.

Part III comprises well-organized material bearing on the problems of research organization, administration and co-operation with other phases of industrial activity. Here is no handbook, but here is wisdom and inspiration to help all engaged in research to understand their environment and to solve the problems of organization of personnel and facilities.

The authors have given freely of their knowledge and appreciation of the problems encountered in the organization of industrial scientific research, a field in which they are respected leaders.—G. T. LORANCE, 125 Gates Ave., Montclair, N.J.

# New Members

The following have been added to the Society's rolls since the list published last month. The designations of grades are the same as those in the 1950 MEMBERSHIP DIRECTORY:

Honorary (**H**)    Fellow (**F**)    Active (**M**)    Associate (**A**)    Student (**S**)

**Askren, Lee T.,** Mechanical Engineer, Eastman Kodak Co. **Mail:** 111 Commodore Pkway, Rochester 10, N.Y. (**M**)

**Brown, Morris E.,** Supervising Design Engineer, Eastman Kodak Co. **Mail:** 48 Roosevelt Road, Rochester 18, N.Y. (**M**)

**Brown, Robert A.,** Physicist, Remington Arms Co., Inc., Physics Section, Bridgeport 2, Conn. (**A**)

**Buescher, R. E.,** Hollywood Sound Inst. **Mail:** 827 4th St., Apt. 102, Santa Monica, Calif. (**S**)

**Caldwell, Philip G.,** Engineer, American Broadcasting Co. **Mail:** 6285 Sunset Blvd., Hollywood, Calif. (**M**)

**Cooper, James B., Jr.,** Supervisor, Photographic Dept., Univ. of Michigan Aeronautical Research Center. **Mail:** 603 Swift St., Ann Arbor, Mich. (**A**)

**Craig, Bob,** Distributor of Photographic Supplies, Craig Movie Supply Co. **Mail:** 8414 Valley Circle, Canoga Pk., Calif. (**M**)

**Culley, Paul E.,** Recording Engineer, Cinecraft Productions, Inc. **Mail:** 2515 Franklin Ave., Cleveland 13, Ohio. (**A**)

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D'Andrea, Matthew J., Free-Lance Technician. **Mail:** 1589 Anderson Ave., Fort Lee, N.J. **(M)**

Decker, Francis W., Motion Picture Technician, U.S. Air Force. **Mail:** 109 Central Ave., Dayton 6, Ohio. **(A)**

Didriksen, Roald W., Television XMTR Supervisor, KPIX Associated Broadcasters, Inc. **Mail:** 1056 Cole St., San Francisco 17, Calif. **(A)**

Edous, John R., Univ. of Southern Calif. **Mail:** 3379 Santa Ana St., Huntington Pk., Calif. **(S)**

Ettlinger, Adrian B., Electrical Engineer, Columbia Broadcasting System, Inc. **Mail:** 84–50 Fleet Court, Rego Park, L.I., N.Y. **(A)**

Exner, William L., Television Engineer, KPIX—Television. **Mail:** 2336-A Jones St., San Francisco 11, Calif. **(A)**

Fouce, Frank, Motion Picture Producer, Theater Owner. **Mail:** 3212 Griffith Blvd., Los Angeles, Calif. **(M)**

Innamorati, Libero, Engineer, Centro Sperimentale Cinematografia. **Mail:** Via Satrico, 43, Rome, Italy. **(A)**

Jennings, James H., Chief Draftsman, Ampro Corp. **Mail:** 7006 N. Monon, Chicago, Ill. **(M)**

Johnson, Charles A., Motion Picture Camera Rentals, Mark Armistead, Inc. **Mail:** 911 N. Formosa Ave., Hollywood, Calif. **(A)**

Kagan, Phillip H., Service Manager, Du-Art Film Laboratories, Inc. **Mail:** 845 Gerard Ave., Bronx 51, N.Y. **(A)**

Kinney, Earl C., Manager, Film Processing Laboratory, Eastman Kodak Co. **Mail:** 1416 Sunset Terrace, Western Springs, Ill. **(M)**

Marino, Louis B., Hack Driver, National Transportation Corp. **Mail:** 911 East River Dr., New York, N.Y. **(A)**

Martin, Gene F., Univ. of Calif., Los Angeles. **Mail:** 11024 Strathmore, Los Angeles 24, Calif. **(A)**

Masters, Richard M., Tufts College Engineering School. **Mail:** 124 Cotton St., Newton, Mass. **(S)**

Maulfair, Robert J., Archer School of Photography. **Mail:** 946 Magnolia, Los Angeles 6, Calif. **(S)**

Mochel, Walter E., Research Supervisor, E. I. du Pont de Nemours & Co., Inc. Wilmington, Del. **(A)**

Muhl, Elinor P., Photographer, Dept. Aeronautical Engineering, Univ. of Minnesota. **Mail:** Rosemount Research Center, Bldg. 704-W, Rosemount, Minn. **(A)**

Niemann, Fred S., Motion Picture Producer. **Mail:** 942 Lake Shore Dr., Chicago 11, Ill. **(M)**

Niemeyer, John H., Industrial Technical Representative, Eastman Kodak Co.

Mail: 204 Keotiak Rd., Park Forest, Chicago Heights, Ill. **(A)**

Pasquariello, Vincent J., Univ. of Calif., Los Angeles. **Mail:** 6208 Homes Ave., Los Angeles 1, Calif. **(S)**

Risk, J. E., Chief Engineer, KSD-TV, The Pulitzer Publishing Co. KSD-TV. **Mail:** 351 Fairway Lane, Kirkwood, Mo. **(A)**

Severdia, Anthony, Television Engineer-Projectionist, Associated Broadcasters, Inc., KPIX. **Mail:** 1440 Shafter Ave., San Francisco, Calif. **(A)**

Snegoff, Mark, Teacher, Univ. of Calif., Los Angeles. **Mail:** 1954 Pinehurst Rd., Los Angeles 28, Calif. **(A)**

Tunnicliffe, William W., Research Associate in Electronics (Airborne Television). **Mail:** 61-A Philips St., Watertown 72, Mass. **(A)**

Verran, Bruce H., Univ. of Calif., Los Angeles. **Mail:** 2036 W. 79 St., Los Angeles 47, Calif. **(S)**

Vinten, Charles, Managing Director, Messrs. W. Vinten, Ltd. **Mail:** 715, N. Circular Rd., London, England. **(A)**

Wentzy, Woodrow P., Head, Dept. Audio-Visual Education and Photography, South Dakota State College, Brookings, S.D. **(A)**

West, Lawrence, Television Camera Man, KPIX (Associated Broadcasters, Inc.). **Mail:** 1010 Curtis St., Albany 6, Calif. **(A)**

Woods, George M., Projectionist-Repairman, Grieme & Fasken Theatres—Johnson's, Inc. **Mail:** Route 5, Wenatchee, Wash. **(A)**

Yuen, Howard A., Radio Engineer, Associated Broadcasters, Inc. **Mail:** 640 Second Ave., San Francisco 18, Calif. **(A)**

### CHANGE IN GRADE

Haines, Jesse H., Television Engineer, A. B. Du Mont Laboratories, Inc. **Mail:** 340 E. Olney Ave., Philadelphia 20, Pa. **(S) to (A)**

Newcombe, Charles R., In Charge, Electronics, Hallen Corp., Burbank, Calif. **Mail:** 1256 Elysian Park Ave., Los Angeles 26, Calif. **(S) to (A)**

### CORRECTION

Payne, Raymond W. **From:** Laboratory Superintendent, Shelly Films, Ltd., Small Arms Administration Bldg., Longbranch, Toronto 14, Ont., Canada; **To:** Laboratory Superintendent, National Film Board of Canada, John & Sussex Sts., Ottawa, Ont., Canada. **Mail:** 931 Bank St., Ottawa, Ont., Canada.

# ～ *New Products* ～

Further information concerning the material described below can be obtained by writing direct to the manufacturers. As in the case of technical papers, publication of these news items does not constitute endorsement of the manufacturer's statements nor of his products.
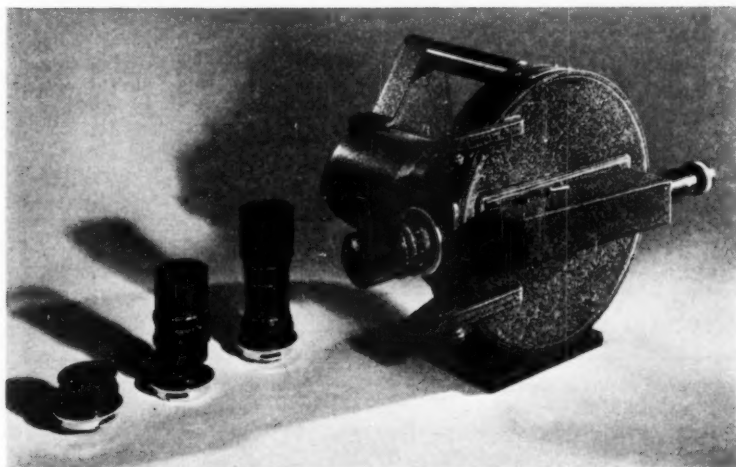


**Fastax High-Speed Motion Picture Cameras** are now manufactured, sold and serviced by Wollensak Optical Co., Rochester, N. Y., as a result of a recent outright purchase from the Western Electric Co. Fastax Cameras will be part of a newly formed division of Wollensak, known as the Technical and Industrial Division in High-Speed Photography. The new division is headed by John H. Waddell who had been with the Bell Telephone Laboratories since 1929. Under his guidance the Fastax was designed and perfected until it is called the world's fastest moving film high-speed camera and also the most versatile device for recording high-speed motion of either repetitious or transient nature. The first Fastax Camera to be designed used 16-mm film and took up to 4000 pictures a second. The second Fastax used 8-mm film at 8000 pictures a second. When a wider angle was desired for ballistics studies, a third Fastax was designed for 35-mm half-frame wide-angle pictures. This camera gives 3500 pictures a second and has an angle view of 40 degrees or a width of field of 71 ft, when the camera is 100 ft from the subject.

**A heat (infrared) deflector** is described in Bulletin MI-318 available from Fish-Schurman Corp., 230 East 45th St., New York 17. It is a filter of multi-layer interference film and is marketed as the XUR-96 Heat Deflector. The manufacturer reports that by installing the deflector at normal incidence in a motion picture carbon arc projector, either of the condenser type utilizing 185 amp or of the reflector type using up to 125 amp, without additional blowers or other artificial cooling it was possible to reduce the heat on the film gate so that no buckling or embossing of the film occurred, and that the deflector is colorless and transmits between 94% and 96% of the visible light and reflects back to the source, depending on what region of the infrared one measures, between 35% and 65%.
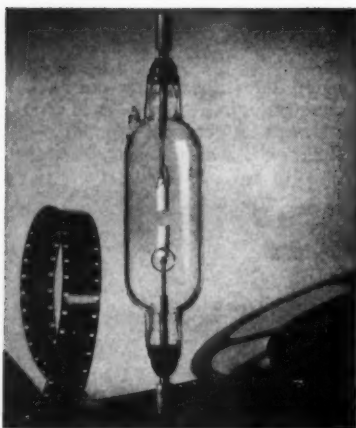
The new G-E Flashtube No. 231 has been developed with opaque shields surrounding the tube's thoriated tungsten electrodes designed to prevent formation of "incandescent trees," which in earlier flashtubes produced film travel "ghost," or double-image effects on the screen. This new flashtube is similar in principle to photographic flashtubes developed by General Electric during the war and since, and which are capable of emitting thousands of intense flashes of light with durations down to one-millionth of a second. This new flashtube for use as a television light source is in production and has a list price of $48.00 plus tax.

# Meetings of Other Societies

Sponsored by the Audio Engineering Society, the second Audio Fair will be held in New York City, October 26–28, at the Hotel New Yorker. There will be two floors of exhibits with demonstrations and technical papers scheduled for each of the three days.

Illuminating Engineering Society, National Technical Conference, Aug. 21–25, Pasadena, Calif.

Biological Photographic Assn., Annual Meeting, Sept. 6–8, Hotel Sheraton, Chicago

Institute of Radio Engineers, West Coast Convention, Sept. 13–15, Long Beach, Calif.

Institute of Radio Engineers, National Electronics Conference, Sept. 25–27, Chicago

Theatre Equipment and Supply Manufacturers' Association, Annual Convention, Oct. 8–11, Stevens Hotel, Chicago

Audio Engineering Society, National Convention, Oct. 26–28, Hotel New Yorker, New York

Optical Society of America, Oct. 26–28, New York

Theatre Owners of America, Annual Convention, Oct. 30–Nov. 2, Shamrock Hotel, Houston, Texas

Acoustical Society of America, Fall Meeting, Nov. 9–11, Boston

President, Executive Vice-President, Editorial Vice-President, Secretary, Convention Vice-President, two Atlantic Coast Governors, two Pacific Coast Governors, and three Governors from the Central Section. In each instance except one, terms are for the two-year period from January 1, 1951, to December 31, 1952. The one special case occurs in the Central Section where the Governor nominee receiving the third largest number of votes serves for one year so that in future elections there will be two vacancies from each section each year.

Voting members who reside within the continental limits of the United States also receive annual election ballots from the Society sections. Each section elects a Chairman and a Secretary-Treasurer for one-year terms and three Managers annually for two-year terms.

Members in the honorary, fellow and active grades are entitled to vote and are urged to do so promptly.

# *Sustaining Members*